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In-season training load quantification of a top elite European soccer male team

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*To my mother, Teresa Isabel, who guide in life me through the years and
make me doing the entire academic course.*

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Abstract

The higher level of competitiveness in soccer lead coaches to a better training load management in order to avoid accumulative fatigue, to keep the best performance possible of their team and, consequently, to prepare the team to win the game. Thus, it is relevant to quantify training load applied to the players to get better the control and monitoring of the team as well as to get knowledge about the periodization applied. Therefore, the general aim of this thesis was to quantify external and internal training load during in-season 2015-2016 from a top elite European soccer male team. For the accomplishment of this purpose, the following sequence was used: (i) literature review of the current subject; (ii) the study of training load quantification during in-season; (iii) the study of training load quantification of one, two and three games week. The main conclusions were: (i) there were minor changes across the in-season period for the internal and external training load variables used; (ii) there was a decrease of training load until the day prior to the match for all variables; (iii) external training load was reduced from the following day of the match until the day prior to the match, however internal training load variables does not reveal the same pattern; (iv) training load applied in weeks with different number of matches seems similar. This thesis allows to obtain references about the periodization pattern observed across a full competitive season and allows generate reference values for elite players that can be considered for the coaches in the control and monitoring of the training load.

Keywords

Soccer Training; Internal Load; External Load; Training Load; Periodization; Training Load Quantification; Global Positioning System; Session Rating of Perceived Exertion; Hooper Index.

Resumo

O aumento da competitividade no futebol tem obrigado aos treinadores uma melhor gestão do treino para prevenir fadiga acumulada da sua equipa, para que seja possível jogar na melhor com elevado rendimento e, consequentemente, ganhar jogos. Dessa forma, torna-se relevante quantificar a carga de treino aplicada aos jogadores e perceber qual o tipo de periodização aplicada. Assim sendo, o objetivo geral da presente tese foi quantificar a carga de treino externa e interna da época 2015-2016, numa equipa europeia elite de classe mundial masculina de futebol. Para operacionalizar o objetivo geral, utilizou-se a seguinte sequência: (i) revisão da literatura; (ii) estudo sobre a quantificação da carga de treino da época completa; (iii) estudo sobre a quantificação da carga de treino em semanas com um, dois e três jogos. As principais conclusões foram: (i) existem alterações mínimas nas variáveis de carga externa e interna usadas durante a época; (ii) existe uma redução da carga de treino no dia antes do jogo em todas as variáveis; (ii) a carga externa vai sendo reduzida desde o primeiro dia após jogo até ao dia anterior ao jogo seguinte, no entanto as variáveis de carga interna nem sempre revelam o mesmo comportamento; (iii) a carga aplicada em semanas com números de jogos diferentes é semelhante. Esta tese permite obter referências sobre o padrão de periodização observado ao longo de uma temporada competitiva completa e permite gerar valores de referência para jogadores de elite que podem ser considerados pelos treinadores no controle e monitorização da carga de treino.

Palavras-chave

Treino de futebol; Carga Interna; Carga Externa; Carga de Treino; Periodização; Quantificação da Carga; Sistema de Posicionamento Global; Perceção Subjetiva de Esforço da Sessão; Índice de Hooper.

Résumé

La compétitivité accrue dans le football a obligé les entraîneurs à mieux gérer l'entraînement pour éviter la fatigue accumulée de leur équipe, afin qu'il soit possible de jouer dans les meilleures conditions et, par conséquent, de gagner les matchs. Ainsi, il devient pertinent de quantifier la charge d'entraînement appliquée aux joueurs, de comprendre le type de périodisation appliqué. L'objectif général de cette thèse était donc de quantifier la charge d'entraînement interne et externe de la saison 2015-2016, au sein d'une équipe de football de haut niveau, composée d'hommes européens. Afin de rendre l'objectif général opérationnel, la séquence suivante a été suivie: (i) revue de la littérature; (ii) quantifier la charge d'entraînement de la saison complète; (iii) quantifier la charge d'entraînement appliquée en semaines avec un, deux et trois matchs. Les principales conclusions sont les suivantes: (i) il y a eu des changements mineurs au cours de la période de la saison pour les variables internes et externes de TL utilisées; (ii) il y a une réduction de la charge d'entraînement la veille du match pour toutes les variables; (iii) la charge externe révélée est réduite dès le lendemain du match jusqu'à la veille du match suivant, cependant les variables de la charge externe ne présentent pas toujours le même comportement; (iv) la charge appliquée pendant les semaines avec un nombre de matchs différents est similaire. Cette thèse permet d'obtenir des références sur le schéma de périodisation observé pendant une saison de compétition complète et de générer des valeurs de référence pour les joueurs d'élite pouvant être prises en compte par les entraîneurs dans le contrôle et le suivi de la charge d'entraînement.

Mots-clés

Entraînement de Football; Charge Interne; Charge Externe; Charge D'entraînement; Périodisation; Quantification de la Charge; GPS; s-RPE; Index Hooper.

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Abbreviations: (A) training duration; (B) total distance; (C) HSD; (CD), central defenders; (WD), wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. a denotes significant difference in CD versus WD, (b) denotes significant difference in WD versus WM, (c) denotes significant difference in WD versus ST, (d) denotes significant difference CM versus WM, all $p < 0.05$.

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Abbreviations: (A) s-RPE; (B) HI; (CD), central defenders; (WD), wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. a denotes significant difference in CD versus WD, (b) denotes significant difference in WD versus WM, (c) denotes significant difference in WD versus ST, (d) denotes significant difference CM versus WM, all $p < 0.05$.

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List of Abbreviations

ANOVA	Analysis of Variance
ATP	Adenosine Triphosphate
au	Arbitrary Units
AvS	Average Speed
CK	Creatine Kinase
CD	Central Defenders
CM	Central Midfielders
CNS	Central Nervous System
CV	Coefficient of Variation
DOMS	Delayed Onset Muscle Soreness
ES	Effect Size
GPS	Global Positioning System
HI	Hooper Index
HR	Heart Rate
HSD	High-speed distance
HSRD	High-speed Running Distance
Hz	Hertz
ITL	Internal Training Load
km	Kilometer
Km/h	Kilometre per hour
MD	Match Day
MD-	Match Day Minus
MD+	Match Day Plus
m	Meters
m/min	Meters per minute
m/s	Meters per second
min	Minutes
RPE	Rating of Perceived Exertion
sec	Seconds

SEE	Standard Error of the Estimate
s-RPE	Session Rating of Perceived Exertion
ST	Strikers
TL	Training Load
U/L	Units per litre
UEFA	Union of European Football Associations
VO ₂ max	Maximal Oxygen Uptake
WD	Wide Defenders
WM	Wide Midfielders

Chapter 1. General Introduction

Elite soccer teams that play in Europe competitions such Union of European Football Associations, (UEFA) Champions League or UEFA European League had a scheduling dictated by external factors (e.g. television subscription rights) and consequently, they have congestive periods by playing two or three games per week. For this reason, the number of weekly soccer training sessions depends on the number of games played each week. Usually, in top elite European teams, training frequency can vary between 2-6 training sessions per week. Moreover, adequate recovery time is required between matches to maximise physiological adaptations and technical/tactical performance and it should also be considered in the periodization model chosen by the coach. (Anderson, Orme et al., 2016a; Duppont et al., 2010; Morgans, Orme, Andreson, Drust & Morton, 2014a; Thorpe, Atkinson, Drust & Gregson, 2016a).

The concept of periodization is a common topic of discussion among coaches and sports scientists. Classically, periodization can be divided into 3 levels: the macrocycle (long-length, lasting 3-4 months); the mesocycle (mid-length, lasting 2-4 weeks); and the microcycle (short-length, lasting 1-7 days). Each macrocycle generally begins with a format of high-volume, low-intensity training and ends with a reverse format of high-intensity, low-volume training (Bompa & Haff, 2009; Matveyev, 1981; Plisk & Stone, 2003). In general, the macrocycle comprises four phases: (a) preparation (general and special); (b) competition; (c) peaking; and (d) transition or active rest. All these phases have different goals and degrees of variation.

However, classic periodization is somewhat difficult to put into practice during soccer trainings, because it is essential that the team is well-prepared for the game every week. For instance, top European players usually participate in 1-2 training sessions between two consecutive matches. For this reason and in this case, coaches can only implement recovery training. (Akenhead, Harley & Tweddle, 2016a; Anderson et al., 2016a, 2016b; Malone et al. 2015; Stevens, Ruiter, Twisk, Savelsbergh & Beek 2017).

In order to ensure proper periodization during the in-season, it is necessary to quantify the training load (TL). The TL is a combination of different variables, such as volume and intensity, that can be controlled during each training session (Impellizzeri, Rampinini & Marcora, 2005). The TL can be divided into two main domains: external and internal. External TL is associated with physical work performed during a training session or match, while internal TL is related to the physiological response to an external training stimulus (Impellizzeri, et al., 2005; Vanrenterghem, Nedergaard, Robinson & Drust, 2017). The TL response can further be subdivided into acute and chronic responses to a given training stimulus. An acute response is related to a training unit or a set of 3-7 training sessions, whereas a chronic response is associated with the accumulation of many training sessions from a single week to several months throughout the entire in-season or annual cycle (Bompa & Haff, 2009).

Taylor (2012) has stated that the most important reasons for monitoring internal and external TL are to prevent injury (29%), to observe the effectiveness of the training program (27%), to maintain performance (22%) and to prevent overtraining (22%). In brief, all data collected regarding TL can help coaches determine whether athletes are ready to compete (Halson, 2014), avoiding negative consequences of fatigue.

Fatigue is a concept linked to training load (Akenhead & Nassis, 2016b; Djaoui, Haddad, Chamaric & Dellal, 2017; Kellis, Katis & Vrabas, 2006; McMorris & Graydon, 1997; Mohr, Kustrup & Bangsbo, 2003, 2005; Saw et al., 2015; Thorpe et al., 2015, 2016a,b; Thorpe, Atkinson, Drust & Gregson, 2017). Fatigue can affect motor and perceptual processing, both of which are associated with physiological and metabolic impairments that can reduce muscular strength capacity, affect coordination, and consequently decrease performance in the next minutes and/or days (Kellis et al., 2006; Kustrup, Zebis, Jensen & Mohr, 2010; McMorris & Graydon, 1997; Mohr et al., 2003, 2005). If training load is not properly controlled, excessive fatigue and overreaching may occur (Brink, Visscher, Coutts & Lemmink, 2012; Thorpe et al., 2017).

According to several authors (Bradley et al., 2009; Di Salvo, Gregson, Atkinson, Tordoff & Drust, 2009; Kustrup et al., 2006; Mohr et al., 2003, 2005; Vigne, Gaudino, Rogowski, Alloatti & Hautier, 2010), the physical demands of a match, such as long distances covered, high-intensity periods of sprinting and jumping can result in fatigue. For instance, it has been well-documented that the distance that players cover at running speed declines significantly from the first to the second half of elite soccer matches (Di Salvo et al., 2009; Kustrup et al., 2010), as well as temporarily following the most intensive periods of the match (Bradley et al., 2009; Di Mascio & Bradley, 2013; Kustrup et al., 2006).

However, the scientific community has only recently begun to study in more detail the in-season periodization of elite soccer teams, specifically training days during weekly microcycles (Akenhead et al., 2016a; Anderson et al., 2016a, 2016b; Malone et al., 2015; Owen, Lago-Peñas, Gómez, Mendes & Dellal, 2017; Stevens et al., 2017). Despite previous attempts to quantify TL in elite soccer players, only a limited number of studies have systematically quantified both acute and chronic responses using external and internal variables, specifically regarding training periodization of top elite European soccer teams.

Considering the aforementioned, the aim of this thesis is to quantify the external and internal TL of elite soccer players during an in-season. Specifically, the purpose aims to analyse data collected during an in-season in one-game weeks and in five microcycles with one-, two- and three-game weeks.

It was hypothesized that training load is lower on training days closer to the next match and that the intensities and volume probably remain constant throughout the competitive period. Moreover, the training load during the microcycle differ with the number of games per week.

This thesis is organised as follows:

Chapter 2 provides an overview of soccer game physiology, fatigue and soccer, soccer periodization and training load in soccer.

Chapter 3 presents the experimental studies developed to accomplish the main aim of this thesis:

- Study 1 investigates internal and external TL quantification of top elite European soccer teams during an entire in-season;
- Study 2 demonstrates the quantification of one-, two- and three-game week schedules in a top elite European soccer team.

A general discussion of the results is presented in Chapter 4, and Chapter 5 presents the main conclusions of this thesis. Lastly, Chapter 6 offers suggestions for future research.

Chapter 2. Literature review

Soccer game physiology

From a physiological perspective, soccer is highly complex because requires different physiological energy systems to meet the physical demands of the game (Malone et al., 2015). This sport is characterised by intermittent bouts of low- and high-intensity activities (Drust, Atkinson, Reilly, 2007). Top elite soccer players cover approximately 10-13 kilometer (km) during a soccer match (Dellal et al., 2011; Di Salvo et al., 2007). When analysed by position, central midfielders (CM) tend to cover a greater total distance than other positions, while central defenders (CD) cover lower total distance than other positions (excluding goalkeepers) during a soccer match (Bradley et al., 2009; Di Salvo et al., 2007). In regard to high-speed running distances (> 14.4 km/h), wide midfielders (WM) cover higher distances compared to other positions (Bradley et al., 2009). According to Mohr, Krustup and Bangsbo (2003), each player performs around 1000-1400 movements that can change every 4-6 seconds (sec) during a match. These movements include accelerations/decelerations, kicking, dribbling and tackling (Bangsbo, 1994a), 30-40 sprints (Bangsbo, Mohr, & Krustup, 2006), more than 700 turns (Bloomfield, Polman & O'Donoghue, 2007) and 30-40 tackles and jumps (Bangsbo et al., 2006). Furthermore, many of these actions could be performed at a high-intensity level (Dupont, Moalla, Guinhouya, Ahmaidi & Berthoin, 2004) and they could be performed with the direct aim of scoring goals to win matches.

Nevertheless, soccer matches are primarily characterised by long durations of moderate- to low-intensity activity (Di Salvo et al., 2007). As such, aerobic metabolism (Stolen, Chamari, Castagna & Wisloff, 2005), humans' main metabolic energy source, is especially important for soccer players. Bangsbo (1994b) has verified the importance for soccer players by affirming that more than 90% of total energy consumption during a match is aerobic metabolism.

Physical requirements of the soccer players

Soccer has been described as stochastic, acyclical and intermittent, and is unique in its variability and unpredictability. Soccer match-play is characterised by its sporadic nature, whereby multidirectional physical actions are combined with an array of technical skills. The games last a total of 90 minutes (min), during which players perform different activities at different intensities (Bangsbo et al., 2006; Bradley et al., 2009; Wallace & Norton, 2014; Wragg, Maxwell & Doust, 2000). During the game, players make 1000-1400 short-duration actions—with and without the ball—that change every 3-5 sec, including running at different velocities, dribbling, tackling, changing direction, accelerating, decelerating, jumping, kicking, running backwards and sideways, disputes, etc., (Mohr et al., 2003) according to game circumstances

(Drust et al., 2007). Moreover, the average player's ball-time possession per game is 44.6 - 74.3 sec, and the number of touches on the ball by individual possession is 1.9 - 2.2 sec, revealing the importance of the game without the ball and speed actions (Dellal et al., 2011). The importance of analysing the intensity and frequency of players' movements throughout the entire match, since approximately 98% of the distance covered by players occurs when they are not in possession of the ball (Reilly & Thomas, 1976). Di Salvo et al. (2007) have observed that only 1.2 - 2.4% of a player's running distance in match-play is covered with possession of the ball. Moreover, 7-12% of the overall distance covered by players is at a high-intensity speed and 1-4% is covered while sprinting (Bradley et al., 2009; Di Salvo et al., 2010).

Distances at different threshold speeds in soccer players

Soccer games last 90 min. There are two halves of 45 min each, with a 15-min halftime break. According to Castellano, Blanco-Villaseñor and Álvarez (2011), the effective time of the game is nearly 50 min, or 55% of the total duration of the game. During this time, top elite players cover between 10-13 km (Bangsbo et al., 2006) at a medium-intensity speed near the anaerobic threshold (80%-90% maximal HR), with an 2.2/18 sec of an intermittent effort profile corresponding a 1:8 ratio of work/rest (Vigne, Gaudino, Rogowski, Alloatti & Hautier, 2010). Furthermore, Drust, Reilly and Cable (2000) have discovered that, in the Football Association Premier League, soccer players undertake an average of 19 sprints every 45 min during match-play. In addition, Strudwick, Reilly and Doran (2002) have observed an average change in activity every 3.5 sec, a bout of high-intensity activity every 60 sec, and a display of maximal effort every 4 min. However, these distance values can differ depending on the system game presented by each team (Bradley et al., 2011) and on the player's position. Thus, soccer players perform low- to moderate-intensity aerobic activities during 80-90% of a match, and only perform high-intensity anaerobic activity during 10-20% a match (Bangsbo, 1994a; Guerra & Barros, 2004; O'Donoghue, 1998; Reilly & Thomas, 1976; Rienzi, Drust, Reilly, Carter & Martin, 2000).

As previously stated, soccer players need to be capable of performing intense, repeated actions and therefore, players need to develop excellent overall fitness, such as speed, muscle strength, anaerobic power, agility and maximal aerobic power (Rampinini, Impellizzeri, Castagna, Coutts & Wisloff, 2009). Players also need to develop a large number of technical and tactical decision-making skills and the ability to perform these skills under pressure and when fatigued (Gabbett, Jenkins & Abernethy, 2009). It has been reported that, after a women's soccer game, the players exhibited changes in several biochemical markers such as creatine kinase, urea, uric acid, myoglobin and C-reactive protein (Andersson et al., 2008), confirming the existence of significant metabolic and mechanical stress (Brancaccio, Maffulli & Limongelli, 2007).

It is estimated that a top elite player performs 150-250 short, intense actions during a game (Mohr et al., 2003). The high ratio of phosphocreatine degradation that occurs during different parts of the game indicates that phosphocreatine is used in adenosine triphosphate (ATP) resynthesize. Thus, aerobic metabolism could be critical for the renewal of phosphocreatine levels (Hof & Helgerud, 2004), since players perform actions under aerobic conditions for most of the game (Castellano et al., 2011; Guerra & Barros, 2004). High-intensity activities are defined as those that are carried out from 5.3-6.3 meters per second (m/s) (Di Salvo et al., 2007). Sprinting specifically is performed at over 7 m/s (Rampinini et al., 2007).

The following table 1 presents the average data collected from a top elite Italian soccer team.

Table 1. Averages distances covered during matches. Adapted from Vigne et al. (2010).

Speed (km/h)	< 5	5-13	13-16	16-19	>19	Average
Percentage (%)	38.9%	29.5%	13.3%	8.4%	9.8%	100%
Distance covered (m)	3477 ± 1433	2631 ± 1097	1192 ± 487	750 ± 314	878 ± 433	8929 ± 3515
Distance/minute (m/min)	46.85 ± 3.85	35.65 ± 5.63	16.40 ± 3.08	1.51 ± 2.48	12.4 ± 405	121 ± 9.57

The literature indicates that, overall, soccer players sprint a total distance of 16 meters (m) in 2-4 sec intervals, and this action is repeated approximately every 70-90 sec of the game, which corresponds to 0.5-3% of effective playing time (Stolen et al., 2005).

Sprinting is crucial because it is utilised at key moments during a match, allowing a player to escape from his opponent and/or to reach a free zone to shoot on the goal or to make a decisive pass (Faude, Koch & Meyer, 2012). Thus, short-sprinting performance can be an important determinant of match-winning actions (Cometti, Maffiuletti, Pousson, Chatard & Maffulli, 2001). During high-intensity sprints (> 6.3 m/s), players cover between 9.9 - 32.5 m of the total distance (average of 19.3 ± 3.2 m) over the course of 17.3 ± 7.7 (range of 3-40) sprints (Di Salvo et al., 2007). During the European Champions League and UEFA Cup, the average number of sprints (> 7 m/s) varied based on the player's position: wide midfielders (35.8 ± 13.4), forwards (attackers; 30.0 ± 12.0), wide defenders (29.5 ± 11.7), central midfielders (23.5 ± 12.2) and central defenders (17.3 ± 8.7) (Di Salvo et al., 2010). In terms of sprinting distance analysed (0-5 m, 5.1-10 m, 10.1-15 m, 15.1-20 and > 20 m), players were found to sprint more in the first section (0-5 m), with differences noted according to each player's position in the English Premier League (Di Salvo et al., 2010).

The greatest covered distances reported are performed by midfielders, who act as links between the defence and the attack (Reilly & Thomas, 1976; Rienzi et al., 2000). Also, midfielders cover more distance at a walking or low-speed running pace, while strikers (also known as forwards) cover more distance at higher speeds and back defenders tend to take

lateral or back actions. In addition, Bloomfield et al. (2007) observed that midfielders cover greater distances because they connect the defence to the team's front line. The same authors also reported that strikers cover less distance than defenders and midfielders and they support a specific training by position. Bangsbo (1994b) has also reported that midfielders cover higher distances (11.5 km) than defenders and strikers, who cover approximately the same mean distance (10-10.5 km).

Midfielders, moreover, appear to engage more frequently in low- to moderate-intensity activity, and for longer durations (Bangsbo, 1994a). In addition, they are stationary for significantly less time than other outfield players (O'Donoghue, 1998), which aligns with their covering greater distances than defenders and strikers. However, strikers have been found to perform the most maximal sprints and for longer durations, followed by midfielders and defenders (O'Donoghue, 1998). Rienzi et al. (2000) have also noted that defenders perform more backwards movement than strikers: high-intensity backwards and lateral movements require an elevated energy expenditure of 20-40% in comparison to forwards running (Reilly & Williams, 2003).

Central midfielders have consistently been found to cover the greatest total distance, while full backs, central midfielders and wide midfielders run greater distances at higher speeds (Bradley et al., 2009; Di Salvo et al., 2007, Di Salvo, Gregson, Atkinson, Tordoff & Drust, 2009). Moreover, the extant research has noted positional differences in maximal oxygen uptake (VO_{2max}), with central midfielders and full backs displaying the highest values (Reilly, Bangsbo, & Franks, 2000). However, other study has found no differences (Haugen, Tønnessen, Hem, Leirstein, & Seiler, 2014). Nevertheless, central midfielders and full backs consistently exhibit the greatest physical capacity during intermittent running tests (Mohr et al., 2003; Reilly et al., 2000). Additionally, central midfielders and full backs perform and complete more passes compared to other positions (Redwood-Brown, Bussell, & Bharaj, 2012).

According to Bush, Barnes, Archer, Hogg and Bradley (2015), there is a positioning evolution of the players in technical and tactical actions. Players in wide and attacking positions covered greater distances and at high-intensities than central defenders and central midfielders between 2006-07 and 2012-13 in the English Premier League. In contrast, the number of passes and pass completion rates of central players were found to have increased over the same period. These evolutionary trends could be attributed to tactical modifications.

Barnes, Archer, Hogg, Bush and Bradley (2014) observed that high-speed running and sprinting distances increased by 30-50% in the English Premier League, while the overall number of passes increased by 40% across seven seasons. Thus, it would appear that the evolution of tactical and technical actions in soccer has changed the physical and performance demands of the game.

Fatigue and Soccer

In the beginning of 20th century, Mosso (1904) concluded that two phenomena affect fatigue: “The first is the reduction of the muscular force. The second is fatigue as a sensation”. In the early 80 sec, Edwards (1981) stated that fatigue is “the failure to maintain the required or expected force”.

Fatigue can be divided in peripheral and central. Peripheral fatigue is associated with a reduction in muscle force production caused by processes distal to the neuromuscular junction (Ament & Verkerke, 2009). According to Hill and Flack (1910), it was concluded that the main factor limiting players’ exercise tolerance was the heart’s ability to pump blood to the active muscles. They predicted that fatigue develops as a consequence of the heart no longer being able to supply oxygen, which is associated with the failure of homeostatic heart function. More recently, emphasis has been placed on the accumulation and difficulty in the removal of excess hydrogenations as a result of anaerobic metabolism. The cardiovascular system is not able to remove waste products from the working muscles (Noakes, 2012). The accumulation of lactic acid directly interferes with contractile ability of the muscle fibres, causing muscle fatigue. Moreover, in many circumstances, fatigue occurs prior to high concentrations of metabolites (such as lactate, Hydrogen ion, extracellular potassium ion) and without disturbances to muscle calcium ion kinetics, high core temperatures or significant hypo hydration (Noakes, 2000).

On the other hand, it has been proposed that fatigue is the result of a failure of the central nervous system (CNS), in which a loss of muscle force occurs through processes proximal to the neuromuscular junction, also known as central fatigue. It is associated with periods of diminished neural drive in the CNS to the muscle (Noakes, St Clair Gibson & Lambert, 2005; Taylor, Todd & Gandevia, 2006). Davis and Bailey (1997), however, suggest that central fatigue is only accepted when experimental findings do not support any peripheral causes of fatigue. Indeed, CNS plays a crucial role in the maintenance of homeostasis (Lambert, Gibson & Noakes, 2005), and the motor cortex of the brain is responsible for the generation of the motor drive and the recruitment of motor units during exercise (Lambert et al., 2005). The brain assumes control of the cognition and recognition of physical sensations that are perceived as fatigue. The perceived fatigue caused by exercise is felt as a “sensation” and is common during exercise. The workload may create such an intense sensation that is perceived as necessary to reduce force to successfully complete the activity (i.e., pacing), or even cease exercise entirely if the sensation becomes too severe (Noakes, 2011).

Running performance declines from the first to the second half during an elite match, or temporarily after the most intense periods (Bendiksen et al., 2012; Bradley et al., 2009; Di Mascio & Bradley, 2013; Krstrup et al., 2006). A reduction in the distance covered could be attributed to fatigue because the muscle glycogen stores have depleted by the end of the match (Bendiksen et al., 2012; Krstrup et al., 2006), with temporary declines after intense periods

of activity during the game that could be associated with intramuscular acidosis or the accumulation of potassium in the muscle interstitium (Mohr, Krstrup & Bangsbo, 2005).

The literature has also reported a reduction of 20-40% in the total amount of high-intensity running, specifically in the last 15 min of the match (Bradley et al., 2009; Mohr et al., 2003). These studies also reveal that 5 min of high-intensity running at the beginning of the match are associated with a 12% decrease in the total distance covered at a high-intensity pace in the subsequent 5 min (Mohr et al., 2003), as well as increased recovery times between high-intensity efforts (Bradley et al., 2009) and an 11% performance reduction in the second half. These results indicate that soccer players exhibit two fatigue patterns: a long fatigue pattern associated with long durations (from start of play to the end of the match) and a short fatigue pattern (temporary fatigue) that depends on each game's unique circumstances (Mohr et al., 2003), and which reduces a player's ability to perform repeated sprints (Krstrup et al., 2006). In regard to tactical actions, less successful teams from the English Premier League cover greater distances at a higher intensity than their successful counterparts (Di Salvo et al., 2009). Also, players from the most successful teams in the Italian Serie A perform more high-intensity activities during a game when in possession of the ball than do players of less successful teams (Rampinini et al., 2009). It also appears that the high-intensity distance covered by players is greater when moving down from the English Premier League (first league) to the Championship (second league) (Bradley et al., 2009).

Soccer Periodization

In team sports, it is possible and desirable to think of periodization in terms of small periods, such as mesocycles, microcycles or simply training units (Bompa & Haff, 2009). In soccer, the in-season period is usually periodized over consecutive microcycles. Here, each microcycle can last 2-7 training days between matches (Reilly, 2007) and TL can be also adjusted to each player or, at least, to each player position to ensure excellent performance and less overall fatigue (Impellizzeri, Rampinini & Marcora, 2005). Previous research has shown that coaches reduce TL after and/or before a match (Akenhead, Harley & Tweddle, 2016; Anderson, Orme et al., 2016; Bangsbo et al., 2006; Impellizzeri et al., 2005; Malone et al., 2015; Stevens, Ruiter, Twisk, Savelsbergh & Beek, 2017). However, training periodization in soccer is not only related to training units (i.e. microcycles or mesocycles), but also to other external factors such as congestive scheduling (Anderson et al., 2016; Clemente et al., 2017; Nédélec et al., 2012). During congested periods, 2-3 games will be scheduled per week over the course of several weeks (Clemente et al., 2017; Nédélec et al., 2012). Thus, top elite soccer teams that participate in European competitions usually play 2-3 games per week, and therefore can only participate in 2-3 training sessions during a weekly microcycle. Consequently, the majority of

these training units are thus mainly for recovery (Bangsbo et al., 2006), making it difficult to coach periodized microcycles to maintain or improve physiological adaptations.

Training Load in Soccer

According to Impellizzeri et al. (2005), TL includes all variables that can be controlled for during training periodization, such as intensity, duration and frequency. The authors further note that TL can be divided into external and internal TL. While external TL is associated with the physical work performed during a training session or match, internal TL is related to various biochemical (physical and physiological) and biomechanical stress responses (Impellizzeri et al., 2005; Vanrenterghem, Nedergaard, Robinson & Drust, 2017). Top elite soccer teams often participate in more than one game per week, and thus play more games per season, which makes it more difficult for coaches to manage players' TL and avoid accumulated fatigue. The quantification of external and internal TL is, therefore, crucial to understanding individual players' responses to each training session to ensure optimal match-day performance and recovery during the entire in-season (Morgans, Adams, Mullen, McLellan & Williams, 2014; Nédélec, 2012). For example, inappropriate TL management can significantly increase the risk of injury (Jones, Griffiths, Mellalieu, 2017; Soligard et al., 2016; Thorpe et al., 2016). Yet, this information is still not enough for players, coaches and therapists to reach sound conclusions regarding the periodization of elite soccer teams (Malone et al., 2015), especially European teams that participate in European competitions.

External Training Load

In order to avoid a higher injury rate (Dupont et al., 2010), higher risk of banal illness (Foster, 1998), low levels of recovery (Nédélec et al., 2012) and, consequently, inappropriate TL, each player's training response needs to be monitored. In this regard, there are many variables that can help to control a player's training response, such as muscular power output, speed, acceleration, time-motion analysis and neuromuscular function (Halsen, 2014). One valid way to control the physical work performed during each training session or match is to use a global positioning system (GPS) to quantify players' movements demands of players during training and competition (Carling, Bloomfield, Nelson & Reilly, 2008; Eniseler, 2005). A GPS enables the direct tracking of a single player (Aughey & Fallon, 2010; Edgecomb & Norton, 2006; MacLeod, Morris, Nevill & Sunderland, 2009) and provides important and detailed information about the player's movements (frequency, duration, distance, impact, velocity and acceleration). Moreover, a GPS can be used to reveal the external TL variables discussed in the present thesis.

Despite the advantages of using a GPS to analyse external TL, GPS data should be interpreted carefully. Indeed, the technology currently available has some limitations in sampling frequency and quality of satellite coverage. One limitation of a GPS is that the data collected only indicates the linear aspects of displacement. Thus, it is necessary to supplement the data with other information that enriches the description of the players' physical demands, such as tackles, contacts, impacts, and directionality of displacement (MacLeod et al., 2009).

Some researchers have also analysed the reliability and validity of GPS devices to measure team sport movements using devices with sampling frequencies of 1 Hz, 5 Hz and 10 Hz (Beato, Devereux & Stiff, 2018; Portas, Harley, Barnes & Rush, 2010; Varley, Fairweather & Aughey, 2012). For instance, Portas et al. (2010) have reported a larger range of error in 1 Hz GPS units compared to 5 Hz units for multidirectional courses. In addition, Varley et al. (2012) used 10 Hz GPS units and have found that these units are up to six times more reliable for measuring constant velocity compared to 5Hz units. The 10 Hz GPS units demonstrated lower coefficient of variation (CV%) values by 2.0 - 5.3% during different starting velocities (1-8 m/s) compared to 5 Hz units (CV% 6.3 - 12.4%). These results suggest that the magnitude of measurement error increases when the sampling frequency of the GPS units is reduced.

Recently, Beato et al. (2018) have supported the validity and reliability of 10 Hz GPS (STATSports Viper) with small errors (< 5%) found only for distance and peak speed. The authors compared 400-m running, 128.5-m sports-specific circuit and 20-m linear running. The distance bias in the 400-m trial, 128.5-m circuit, and 20-m trial was $1.99 \pm 1.81\%$, $2.7 \pm 1.2\%$, and $1.26 \pm 1.04\%$, respectively. Peak speed measured by the GPS was 26.3 ± 2.4 km/h, and criterion was 26.1 ± 2.6 km/h, with a bias of $1.80 \pm 1.93\%$. In addition, increases in velocity and multidirectional motion decrease measurement accuracy (Borresen & Lambert, 2009; Portas et al., 2010). Portas et al. (2010) have also reported an increase in standard error of the estimate (SEE%) values across various multidirectional courses, ranging from 45-180 degrees turning actions (2.4 - 6.8 SEE%), as compared to straight line running (2.6 SEE%). However, it should be noted that, even with the new units, accuracy is greater when measuring distance covered at running speeds of lower intensity, while soccer is a sport characterised by short runs or sprinting runs sequenced together (Castellano, 2011; Jennings, Cormack, Coutts, Boyd & Aughey, 2010a; Portas, et al., 2010; Varley et al., 2012). More recently, Rampinini et al. (2015) analysed a linear running course at different intensities, with both acceleration and deceleration movements, to recreate demands similar to those seen in soccer. Compared to the total distance recorded by the 10 Hz GPS unit, 1.9% and 4.7% error were found for total distance and high-speed running, respectively. It should also be noted that the error for very high-speed running (> 20 km/h) was found to be 10.5%. Several studies have indicated that additional error may be introduced into measures when a change of direction occurs, especially at higher velocities (Coutts & Duffield, 2010; Jennings, Cormack, Coutts, Boyd & Aughey, 2010b).

Internal Training Load

Rate of Perceived Exertion

Since the development of the original Borg scale (Borg, 1970) to control the rating of perceived exertion (RPE), several different adaptations have been developed to better control individual exercise intensity, such as, the 10-point scale developed by Foster (Foster et al., 2001). This method of assessing RPE by first calculating the session-RPE (s-RPE) is referred to as the Foster or s-RPE scale and was adapted from the Borg CR10-scale (Borg, 1982) (see table 2). Despite several critical differences between the CR-10 and Foster's 0-10 scales in the numerical, psychometric properties and semantic descriptors, they are similarly used to determine an individual's internal response and/or physiological stress to an external stimulus and to provide information regarding their perceived effort post-training or competition. It is clear from the literature that Foster's scale has proven to be practical, simple to apply, and a popular and valid method of estimating training load for a wide range of activities (Borrenson & Lambert, 2008; Burgess & Drust, 2012; Casamichana, Castellano, Calleja, Román & Castagna, 2013; Coutts, Rampinini, Marcora, Castagna & Impellizzeri, 2009; Dellal, Drust & Lago-Penas, 2012; Foster et al., 2001, 1995; Foster, 1998; Haddad, Stylianides, Djaoui, Dellal & Chamari, 2017; Impellizzeri, Rampinini, Coutts, Sassi & Marcora, 2004; Scott, Lockie, Knight, Clark & Janse de Jonge, 2013).

Table 2. Rating of perceived exertion scale

Foster s-RPE scale (Retrieved from Foster et al., 2001)		Borg CR10-scale (Borg, 1982)	
Rating	Descriptor	Rating	Descriptor
0	Rest	0	Nothing at all
		0,5	Very, very weak (just noticeable)
1	Very, very easy	1	Very weak
2	Easy	2	Weak (light)
3	Moderate	3	Moderate
4	Somewhat hard	4	Somewhat strong
5	Hard	5	Strong (heavy)
6	.	6	
7	Very hard	7	Very Strong
8	.	8	
9	.	9	
10	Maximal	10	Very, very strong (almost max)
		.	Maximal

Moreover, RPE is also often combined with other variables, such as session duration, heart rate (HR), and blood lactate, to provide additional insights into the internal load experienced by athletes. Thus, the s-RPE is a metric used to quantify internal TL and a product of the duration and intensity reported from a category ratio modified Borg scale (Foster et al., 2001; Foster et al., 1995).

Foster et al. (1995) examined the relationship between known physiological intensity measures, such as HR reserve and blood lactate accumulation and found that s-RPE was useful for determining intensity. This simple method has been shown to be valid and reliable, with individual correlations between session RPE and summated HR zone scores ranging between $r = 0.75$ and $r = 0.90$ (Foster, 1998). Some years later, Foster et al. (2001) compared s-RPE values to HR-based training scores, in which time spent in various HR zones (10% incremental zones from 50% - 100%) were multiplied by a weighted value (1-5). While the s-RPE scores tended to overestimate TL, the correlation with the HR scores were consistent across training methods. Impellizzeri et al. (2004) compared s-RPE values with multiple HR-based internal TL scores and found strong correlations ($r = 0.50$ to 0.85) with all HR-based methods. Subsequent research in soccer training has identified individual correlations between RPE and HR zones (range from $r = 0.54$ to $r = 0.78$), and a correlation of $r = 0.84$ has also been reported in endurance athletes (Borrenson & Lambert, 2008).

In addition, in soccer it is possible to perform multiple training sessions on a single day, and thus collect the corresponding s-RPE data. By using Foster's (2001) 10-point scale multiplied by the session duration (volume), it is possible to provide an overall global score for session TL. When multiple training sessions are performed on a single day, the TL scores are summated to create a daily TL. The TL for each week can then be summated to create a weekly TL. This method is significantly correlated with several methods that are based on HR monitoring (Impellizzeri et al., 2004).

For quantifying internal TL, RPE is cost-effective, easy to collect, and it does not require a specialist or technical expertise. Indeed, RPE only requires some procedures to effectively determine internal TL. Soccer players must be familiar with the RPE scale used to collect regular data. Otherwise, the results may under- or over-represent the actual values. In addition, data also needs to be collected individually to prevent peer pressure from other players influencing the given rating. It is also possible to use a custom-designed application on a portable computer tablet, whereby players can select their RPE rating by touching the respective score on the tablet, which is then automatically saved to the player's profile. This method can help minimise factors that influence a player's RPE rating, such as peer pressure or replicating other players' ratings (Burgess & Drust, 2012). According to Borresen and Lambert (2009), RPE presents a strong correlation with HR during steady-state exercise and high-intensity interval cycling training, but not as well during short-duration, high-intensity soccer drills. Furthermore, a meta-analysis reported that, while RPE is a valid means of assessing

exercise intensity because RPE scales are related to physiological parameters such as lactate, HR and $\text{VO}_2\text{máx}$, the validity may not be as high as previously thought (Chen, Fan & Moe, 2002). For example, the weighted mean validity coefficients for HR, blood lactate, and percent of maximal oxygen uptake ($\text{VO}_2\text{máx}$) were 0.62, 0.57, and 0.64, respectively (Chen et al., 2002).

Moreover, the RPE scales are related to physiological parameters such as lactate, HR, $\text{VO}_2\text{máx}$ (Chen et al., 2002) and, although they were initially proposed for individual endurance disciplines (Foster et al., 1995), recent research has shown that they are useful to quantify TL in team sports (Foster et al., 2001), particularly in soccer (Casamichana, 2013; Impellizzeri et al., 2004; Scott et al., 2013). Although a wide variety of methods can be used to assess internal load, RPE is still considered a valid and objective method (Dellal et al., 2012; Haddad et al., 2017). For instance, Impellizzeri et al. (2004) used the RPE method to quantify TL in junior soccer players and assess the correlations between RPE and different load quantification methods based on HR. They found significant correlations between RPE and HR-based load quantification methods, especially between the methodologies based on RPE. Alexiou and Coutts (2008) then replicated the study with elite soccer players, and also concluded that the RPE method is a good internal load indicator since it significantly correlates with HR. Moreover, Coutts et al. (2009) evaluated the relationship between HR, RPE and lactate in different soccer training exercises, and have concluded that the RPE method is a more valid indicator of overall exercise intensity than any of the other indicators alone. Finally, Gabbet and Domrow (2007) have found significant correlations between HR and blood lactate concentration, suggesting the use of the RPE method.

In support of its practical application in soccer drills, studies such as Dellal et al. (2011) and Hill-Haas, Dawson, Coutts and Rowsell (2009) used RPE scales to determine exercise intensity and have confirmed its validity for quantifying TL. To prove the robustness of this method, Haddad et al. (2013) further showed that the RPE method can be used to quantify TL, although one must always consider the possibility that players may overestimate or underestimate TL (Borresen & Lambert, 2008). Haddad et al. (2013) also recommended that individual comparisons between players should be avoided and that results should be interpreted to provide an overall perspective of the assessed training or task.

Additionally, Casamichana et al. (2013) compared s-RPE to the Edwards (1993) method of calculating internal TL based on HR data (the time in which the athlete remained in each zone during each session is multiplied by: Zone 1 - 50 to 60% HRmax, factor 1/; Zone 2 - 60 to 70% HRmax, factor 2/; Zone 3 - 70 to 80% HRmax, factor 3/; Zone 4 - 80 to 90% HRmax, factor 4/; Zone 5 - 90 to 100% HRmax, factor 5). Based on all of the aforementioned studies, it is reasonable to state that the s-RPE measure can be utilised across training modalities to provide a good measure of internal TL. Recently, RPE-derived TL was reported to correlate significantly with high-speed running distance, acceleration and number of impacts in elite soccer players (Gaudino et al., 2015).

Recently, Haddad et al. (2017) conducted a review regarding validity ecological usefulness and influencing factors regarding s-RPE. The authors confirmed the validity, good reliability and internal consistency of this variable in several sports and physical activities with men and women of different age categories with different expertise levels. The same authors stated that s-RPE could be used as “standing alone” method to control TL but recommend its use with other parameters such as GPS measures and Hooper Index questionnaire. Also, it was recommended individualization in TL assessment as a key to performance optimization.

Nevertheless, RPE could also be an oversimplification of the psychophysiological perceived exertion and a non-conclusive measure to capture the wide range of sensations experienced (Ferraz et al., 2017, 2018; Renfree, Martin, Micklewright & Gibson, 2014). Moreover, when RPE is collected minutes following the end of each training session, it would be pertinent to check if there is some atypical variation during the training session, as sustained by Ferraz et al. (2018). Wallace, Statterry and Coutts (2009) assessed the ecological validity of the s-RPE method to quantify internal TL in comparison to HR and distance covered, and have found that an athlete’s and a coach’s perception of internal load differs when using the s-RPE method: athletes have a tendency to report higher training intensities than coaches during sessions designed to be easy. Furthermore, lower training intensities were reported during sessions designed to be difficult (Wallace et al., 2009).

Wellness questionnaires

The Hooper index (HI) emerged as a reliable method for the monitoring athletes’ wellness by collecting further information about player fatigue, stress, muscle soreness and sleep perception (Hooper & Mackinnon, 1995). As a subjective measure, the HI is relatively simple to apply, cheap and non-invasive. Additionally, it exhibits superior sensitivity and greater consistency than other objective measures, such as heart rate or saliva measures, and could reveal relevant data related to acute and chronic TL (Saw, Main & Gastin, 2016).

The HI was recently utilised to monitor player wellness during a 4-day FIFA international futsal tournament (Charlot, Zongo, Leicht, Hue & Galy, 2016) in addition to a 2-month study on cycling performance (Chamari et al., 2016).

In soccer, HI has recently been shown to be a viable tool for managing training load in soccer players (Clemente et al., 2017; Fessi et al., 2016; Haddad et al., 2013; Rabbani and Buchheit, 2016; Thorpe et al., 2015).

One investigation, however, found no association between the HI and RPE (Haddad et al., 2013). Clemente et al. (2017) studied associations between s-RPE and the HI. Their results indicate that significant and negative small-to-moderate correlations exist between s-RPE and the HI in

the weeks with two matches, but not in the weeks with only one match. They also found that HI and s-RPE differ significantly based on position.

Fessi et al. (2016) analysed the HI scores of professional soccer players during the pre-season and the in-season and report higher values during the pre-season ($p < 0.01$). For instance, Rabbani and Buchheit (2016) applied a different approach to young soccer players by studying the influence of ground travel on HI scores. They have found significant and positive correlations between actual HI scores and traveling distance to away locations (r range: 0.70 to 0.87). They also noticed that ground-travel-induced impairment of wellness is associated with distance to away locations. Lastly, Thorpe et al. (2015) analysed wellness scores using the HI and found that perceived ratings of fatigue are sensitive to daily fluctuations in high-speed running distance in elite soccer players. However, this study only examined 17 days of the entire in-season, and therefore the relationship between the use of the HI and s-RPE is limited.

Further research is thus needed to validate the aforementioned findings and regarding a complete season. In addition, sleep loss or deprivation can have significant effects on performance, motivation, perception of effort and cognition, and numerous other biological functions (Halson, 2014). Therefore, monitoring sleep quality and quantity can be useful for early detection and intervention before significant performance and health decrements are observed. Nevertheless, HI is a cost-effective method that can be used to easily assess sleep. Thus, the use of simple diaries indicating players' hours of sleep and perceived sleep quality can be useful and provide further insight.

Creatine Kinase

Another way to monitor internal TL is through biochemical indicators, such as blood, salivary and urinary parameters. The creatine kinase (CK) activity is often a popular measure due to the simplicity of the sample collection and analysis. However, variability of this measure is very high and a poor temporal relationship with muscle recovery exists. Nevertheless, this statement is not consensual because some studies (Budgett, Koutedakis, Walker, Parry-Billings, & Newsholme, 1989; Kirwan et al., 1988) state that high CK levels are related to high-intensity exercise and could be considered a good marker of overtraining.

Meyer and Meister (2011) has shown that CK values can increase throughout the season. This research studied a large sample ($n = 400$) of top elite soccer players and reported significant differences between the first day of data collection in July (~ 183 U/L) and the data collected in February/March (~ 331 U/L). These results are quite similar to the elite professionals observed in a posterior study (Silva et al., 2014).

In addition, Heisterberg et al. (2013) have shown that CK increases during the pre-season due to higher values of TL. The data shows an increase of ~300 U/L to ~500 U/L during the pre-season period, which returned to ~300 U/L throughout the in-season (Heisterberg et al., 2013).

Furthermore, Nedelec et al. (2012) reported that 24-120 h are needed to normalise metabolic disturbances. Since significant correlations exist between CK and running speeds (> 4 m/s) and accelerations and decelerations over a certain magnitude (moderate to high), it has been suggested that a certain intensity of movement at those speeds is required for the movement to be strongly associated with CK levels (Young, Hepner & Robbins, 2012).

It is relevant to note that high CK values can occur in the absence of overtraining syndrome (Flynn et al., 1994) and within the normal range of athletes (Budgett et al., 1989). Thus, it is relevant to state that CK values are highly dependent on the player assessed and are highly affected by the activity performed during the previous days. Moreover, in soccer, it is possible that a player's position affects the results. Therefore, individual TL must be considered and analysed in addition to CK values for a better interpretation of the results (Heisterberg et al., 2013). Also, CK is an important marker to control daily training sessions. For reference, CK can range from 82-1083 U/L in soccer players, while the upper value can reach 1492 U/L (Mougios, 2007).

The use of biochemical, hormonal and/or immunological measures as indicators of internal load has not yet been consistently applied within the research in this area. In addition, these measures are costly, time consuming and difficult to apply to soccer training sessions (Twist & Highton, 2013).

Chapter 3. Experimental Studies

Study 1

In-season internal and external training load quantification of an elite European soccer team

Abstract

Elite soccer teams that participate in European competitions need to have players in the best physical and psychological status possible to play matches. As a consequence of congestive schedule, controlling the training load (TL) and thus the level of effort and fatigue of players to reach higher performances during the matches is therefore critical. Therefore, the aim of the current study was to provide the first report of seasonal internal and external training load that included Hooper Index (HI) scores in elite soccer players during an in-season period. Nineteen elite soccer players were sampled, using global position system to collect total distance, high-speed distance (HSD) and average speed (AvS). It was also collected session rating of perceived exertion (s-RPE) and HI scores during the daily training sessions throughout the 2015-2016 in-season period. Data were analysed across ten mesocycles (M: 1 to 10) and collected according to the number of days prior to a one-match week. Total daily distance covered was higher at the start (M1 and M3) compared to the final mesocycle (M10) of the season. M1 (5589 meters (m)) reached a greater distance than M5 (4473 m) (effect size (ES) = 9.33 [12.70, 5.95]) and M10 (4545 m) (ES = 9.84 [13.39, 6.29]). M3 (5691 m) reached a greater distance than M5 (ES = 9.07 [12.36, 5.78]), M7 (ES = 6.13 [8.48, 3.79]) and M10 (ES = 9.37 [12.76, 5.98]). High-speed running distance was greater in M1 (227 m), than M5 (92 m) (ES = 27.95 [37.68, 18.22]) and M10 (138 m) (ES = 8.46 [11.55, 5.37]). Interestingly, the s-RPE response was higher in M1 (331 arbitrary units (au)) in comparison to the last mesocycle (M10, 239 au). HI showed minor variations across mesocycles and in days prior to the match. Every day prior to a match, all internal and external TL variables expressed significant lower values to other days prior to a match ($p < 0.01$). In general, there were no differences between player positions. Conclusions: Our results reveal that despite the existence of some significant differences between mesocycles, there were minor changes across the in-season period for the internal and external TL variables used. Furthermore, it was observed that match day minus (MD-1) presented a reduction of external TL (regardless of mesocycle) while internal TL variables did not have the same record during in-season match-day-minus.

Keywords: Soccer Training; Internal Load; External Load; Training Load; Periodization.

Introduction

The knowledge of internal and external training load (TL) helps coaches to prevent increased levels of fatigue, and higher risk of illness and injury (Jones, Griffiths & Mellalieu, 2017). Also, it helps coaches to design an effective individual and group training periodization in elite team sports (Djaoui, Haddad, Chamaric & Dellal, 2017; Jaspers, Brink, Probst, Frencken & Helsen, 2017; Malone et al., 2015, 2018; Nédélec, 2012; Stevens, Ruiter, Twisk, Savelsbergh & Beek, 2017). However, it is only recently that some studies have described the in-season training periodization practices of elite football teams in more detail, including a comparison of training days within weekly microcycles (Akenhead, Harley & Tweddle, 2016; Anderson et al., 2016; Malone et al., 2015; Stevens et al., 2017). As an example, Malone et al. (2015) found that a lowering of TL in the last training day immediately before any given match differed from the other training days on several internal and external TL load variables such as session rating of perceived exertion (s-RPE), plus total distance and average speed, respectively. The same authors stated that the need to win matches does not allow to reach of a specific peak for strength and conditioning (Malone et al., 2015). In addition, some studies have shown limited variation through the in-season and have suggested that training in elite soccer has a regular load pattern (Clemente et al., 2017; Malone et al., 2015, 2018; Morgans, Adams, Mullen, McLellan & Williams, 2014).

Moreover, several authors (Clemente et al., 2017; Hooper & Mackinnon, 1995; Impellizzeri, Rampinini & Marcora, 2005; Jones et al., 2017) have claimed that it is also very important to monitor elite athletes' health to provide further information concerning the details of player fatigue, stress, muscle soreness and sleep perception. These variables are commonly associated with psychophysiological stress responses, such as rating of perceived exertion or Hooper Index (HI) scores, also recognized as internal training load (ITL) (Impellizzeri et al., 2005; Vanrenterghem, Nedergaard, Robinson & Drust, 2017). On this issue, a valid and simple way to control internal TL is the session rating of perceived exertion (s-RPE) which showed correlations to the heart frequency training zones (Foster, 1998). Furthermore, another way to quantify the level of fatigue, stress, muscle soreness and the quality of sleep is the Hooper Index (Hooper & Mackinnon, 1995).

However, the simultaneous use of s-RPE and HI is limited. In fact, very few authors have studied the relationship between the use of the HI and s-RPE (Clemente et al., 2017; Haddad et al., 2013). Here, Clemente et al. (2017) found a correlation between s-RPE and HI levels, and negative correlations between s-RPE and muscle soreness ($p = -0.156$), s-RPE and sleep ($p = -0.109$), s-RPE and fatigue ($p = -0.225$), ITL and stress ($p = -0.188$) and ITL and HI ($p = -0.238$) in 2-game weeks. On the other hand, Haddad et al. (2013) failed to observe any association between HI and RPE. Therefore, further research is needed to clarify this issue, specifically to validate these results during in-season. Subsequently, it is also necessary to quantify the external TL that is associated with the total amount of workload performed during training

sessions and/or matches (Impellizzeri et al., 2005; Vanrenterghem et al., 2017). According to Casamichana, Castellano, Calleja-Gonzalez, San Román and Castagna (2013) and Halson (2014) one easy and practical way to control training response for each player (e.g. frequency, time, total distance and distances of different exercise training intensity) is time-motion analysis by using a global positioning system (GPS).

Nowadays, researchers study the data collected during short training microcycles of 1-2-3 weeks (Anderson et al., 2016; Clemente et al., 2017; Impellizzeri et al., 2005; Owen et al., 2016), in mesocycles consisting of 4-10 weeks (Gaudino et al., 2013; Impellizeri, Rampinini, Coutts, Sassi & Marcora, 2004; Scott, Lockie, Knight, Clark & Janse de Jonge, 2013) and during longer training periods of 3-4 months (Alexiou & Coutts, 2008; Casamichana et al., 2013) and 10-month periods (Morgans et al., 2014). However, most of these studies have provided limited information regarding the TL, using only the duration and RPE without the inclusion of other internal and external TL variables such as HI or data collected from GPS. In addition, few studies (Clemente et al., 2017; Malone et al., 2015, 2018) have attempted to quantify TL with respect to changes between mesocycles and microcycles (both overall and between player's positions) across an in-season.

Finally, the literature is somewhat inconclusive about establishing differences in TL for player positions not only amongst training sessions but also during the in-season across a full competitive season regarding training sessions, but there is information related to match-play data that reveals some differences for player positions (Bradley et al., 2009; Malone et al., 2015). Therefore, the purpose of this study was twofold: a) quantify external TL in an elite professional European soccer team that played Union of European Football Associations (UEFA) competitions across ten months of the in-season 2015/16 and b) quantify the internal TL using s-RPE and HI. For this purpose, we divided the in-season into ten months, following Morgans et al. (2014), and used the match day minus approach used by Malone et al. (2015) for data analysis. Additionally, we also compared player positions for both situations. We hypothesized that training load is lower on training days closer to the next match and that the intensities and volume remain constant throughout the competitive period.

Materials and methods

Participants

Nineteen elite soccer players with a mean \pm SD age, height and mass of 26.3 ± 4.3 years, 183.5 ± 6.6 cm and 78.5 ± 6.8 kg, respectively, participated in this study. The players belong to a team that participated in UEFA Champions League. The field positions of the players in the study consisted of four central defenders (CD), four wide defenders (WD), four central

midfielders (CM), four wide midfielders (WM) and three strikers (ST). Inclusion criteria were regular participation in most of the training sessions (80% of weekly training sessions); the completion of at least 60 minutes (min) in one match in the first half of the season and one match in the second half of the season. All participants were familiarised with the training protocols prior to the investigation and gave their written consent to be included in the project. The study was conducted according to the requirements of the Declaration of Helsinki and was approved by Ethics Committee of the Research Centre for Sports Sciences, Health and Human Development, Vila Real, Portugal.

Design

TL data were collected over a 39-week period of competition where occurred 50 matches during the 2015-2016 annual season. The team used for data collection competed in four official competitions across the season, including UEFA Champion league, the national league and two more national cups from their own country. For the purposes of the present study, all the sessions carried out as the main team sessions were considered. This refers to training sessions in which both the starting and non-starting players trained together. Only data from training sessions were considered. Data from rehabilitation or additional training sessions of recuperation were excluded. This study did not influence or alter the training sessions in any way. Training data collection for this study was carried out at the soccer club's outdoor training pitches. A total of 2981 individual training observations were collected during In-season. Total minutes of training sessions included warm-up, main phase and slow down phase plus stretching. A total of 349 individual observations contained missing data due to factors outside of the researcher's control (eg, technical issues with equipment).

Methodology

The in-season phase was divided into 10 mesocycles or 10 months, respectively, as used by Morgans et al. (2014) and because the coaches and staff of the club work by months. Training data were also analysed in relation to the number of days away from the competitive one-match week (i.e., match day minus). In a week with only one match, the team typically trained five days a week (match day [MD] minus [-]; MD-5; MD-4; MD-3; MD-2; MD-1), plus one day after the match (MD+1). This approach was used by Malone et al. (2015).

External training load - training data

A portable global positioning system (GPS) units (Viper pod 2, STATSports, Belfast, UK) was used to monitor the physical activity of each player (external TL). This device provides position velocity and distance data at 10 Hz frequency. The use of the device by each player is reported in Oliveira et al. (2019). All players wore the same GPS device for each training session in order to avoid inter unit error (Jennings, Cormach, Coutts, Boyd & Aughey, 2010a,b). Previously, this

GPS system have been able to provide valid and reliable estimates of instantaneous and constant velocity movements during linear, multidirectional and soccer-specific activities (Beato, Devereux & Stiff, 2018). Following recommendations by Maddison and Ni Mhurchu (2009), all devices were activated 30 min before data collection to allow the acquisition of satellite signals and synchronise the GPS clock with the satellite's atomic clock. GPS data were then downloaded using the respective software package (Viper PSA software, STATSports, Belfast, UK) and were clipped to involve the main team session (i.e. the beginning of the warm up to the end of the last organised drill). The number of satellites visualized by this unit, as well as the horizontal dilution of position, is not reported by this GPS model, and therefore, are not reported in this study.

The metrics selected for the study were total duration of training session, total distance, high-speed distance (HSD, above 19 Km/h) and average speed (AvS).

Internal training load - training data

Approximately 30 min before each training session, each player was asked to provide the Hooper Index scores. This index includes four categories: fatigue, stress, muscle soreness and quality of sleep of the night that preceded the evaluation. It was used the Hooper index scale of 1-7, in which 1 is very, very low and 7 is very, very high (for stress, fatigue and muscle soreness levels) and 1 is very, very bad and 7 is very, very good (for sleep quality). The summation of the four subjective ratings is the Hooper Index (Hooper & Mackinnon, 1995).

Thirty minutes following the end of each training session, players were asked to provide an RPE rating, 0-10 scale (Borg, 1970). Players were prompted for their RPE individually using a custom-designed application on a portable computer tablet. The player selected their RPE rating by touching the respective score on the tablet, which was then automatically saved under the player's profile. This method helped minimise factors that may influence a player's RPE rating, such as peer pressure and replicating other player's ratings (Burgess & Drust, 2012). Each individual RPE value was multiplied by the session duration to generate a session-RPE (s-RPE) value (Foster et al., 1995, 2001; Impellizzeri et al., 2004). Further details regarding s-RPE are reported in Oliveira et al. (2019).

Statistical Analysis

Data were analysed using SPSS version 22.0 (SPSS Inc., Chicago, IL) for Windows statistical software package. Initially, descriptive statistics were used to describe and characterize the sample. Shapiro-Wilk and the Levene tests were used to assumption normality and homoscedasticity, respectively. ANOVA was used with repeated measures with Bonferroni post hoc, once variables obtained normal distribution (Shapiro-Wilk > 0.05), to compare 10 mesocycles and to compare days away from the competitive match fixture. Also, it was used

ANOVA Friedman and Mann-Whitney tests were used for the variables that not obtained normal distribution to compare different moments and different player positions. Results were significant with $p \leq 0.05$. The effect-size (ES) statistic was calculated to determine the magnitude of effects by standardizing the coefficients according to the appropriate between-subjects standard deviation and was assessed using the following criteria: < 0.2 = trivial, 0.2 to 0.6 = small effect, 0.6 to 1.2 = moderate effect, 1.2 to 2.0 = large effect and > 2.0 = very large (Hopkins, Marshall, Batterham & Hanin, 2009). The associations between s-RPE and HI scores were tested with Spearman correlation. Data are represented as mean \pm SD.

Results

In-Season Mesocycle Analysis

The results indicate that duration of training sessions (Table 1) had more minutes in M1 than in other mesocycles and M5 was the lowest. There were no differences between player positions during in-season (figure 1).

Table 1. External Training Load Data during the ten mesocycles for squad average, Mean \pm SD

Mesocycle (M)	Number of matches	Number of training sessions	Training Duration (min)	Total Distance (m)	Average speed (m/min)	HSD (m)
M1	4	16	81.6 \pm 1.1 ^{c, d, e, g, h, i, *}	5589.1 \pm 100.1 ^{d, i, *}	68.6 \pm 1.1	227.0 \pm 13.7 ^{d, e, f, g, h, i, *}
M2	5	20	78.4 \pm 1.6 ^{d, i, *}	5248.2 \pm 156.2 ^{b, i, *}	66.8 \pm 0.9 ^{b, *}	192.3 \pm 17.0 ^{d, g, *}
M3	4	18	77.4 \pm 1.9 ^d	5691.4 \pm 132.1 ^{d, f, i, *}	74.0 \pm 1.7 ^{i, *}	181.9 \pm 18.9 ^{d, *}
M4	5	18	72.3 \pm 1.6	5111.4 \pm 173.9	70.7 \pm 2.2	152.2 \pm 15.4 ^{d, *}
M5	6	20	63.6 \pm 2.4 ^{f, g, i, *}	4473.5 \pm 136.4 ^{e, f, *}	71.0 \pm 2.1 ^{i, *}	92.3 \pm 6.6 ^{e, f, g, *}
M6	8	20	71.7 \pm 1.8	5231.8 \pm 123.0 ^{i, *}	73.2 \pm 1.7 ^{i, *}	162.9 \pm 15.3
M7	5	19	75.5 \pm 1.7	5041.9 \pm 70.5 ^{i, *}	67.2 \pm 1.9	133.6 \pm 10.3
M8	4	20	74.5 \pm 1.2	5149.5 \pm 112.5 ^{i, *}	69.3 \pm 1.3 ^{i, *}	157.8 \pm 15.4
M9	7	18	72.9 \pm 1.8	5026.7 \pm 204.1	69.0 \pm 2.1 ^{i, *}	144.8 \pm 15.9
M10	4	20	73.3 \pm 1.3	4545.4 \pm 111.7	62.2 \pm 1.6	138.5 \pm 14.7

min= minutes; m=meters; HSD = high-speed distance. a denotes difference from M2, b denotes difference from M3, c denotes difference from M4, d denotes difference from M5, e denotes difference from M6, f denotes difference from M7, g denotes difference from M8, h denotes difference from M9, i denotes difference from M10, all $p < 0.05$, * very large effect.

For external load, total distance tended to decrease during in-season. M1 and M3 obtained a greater distance. There were significant differences between player positions in M1 for WD vs WM (ES = 4.87 [2.92, 6.82]), CM vs WM (ES = 5.07 [3.06, 7.09]) (figure 1).

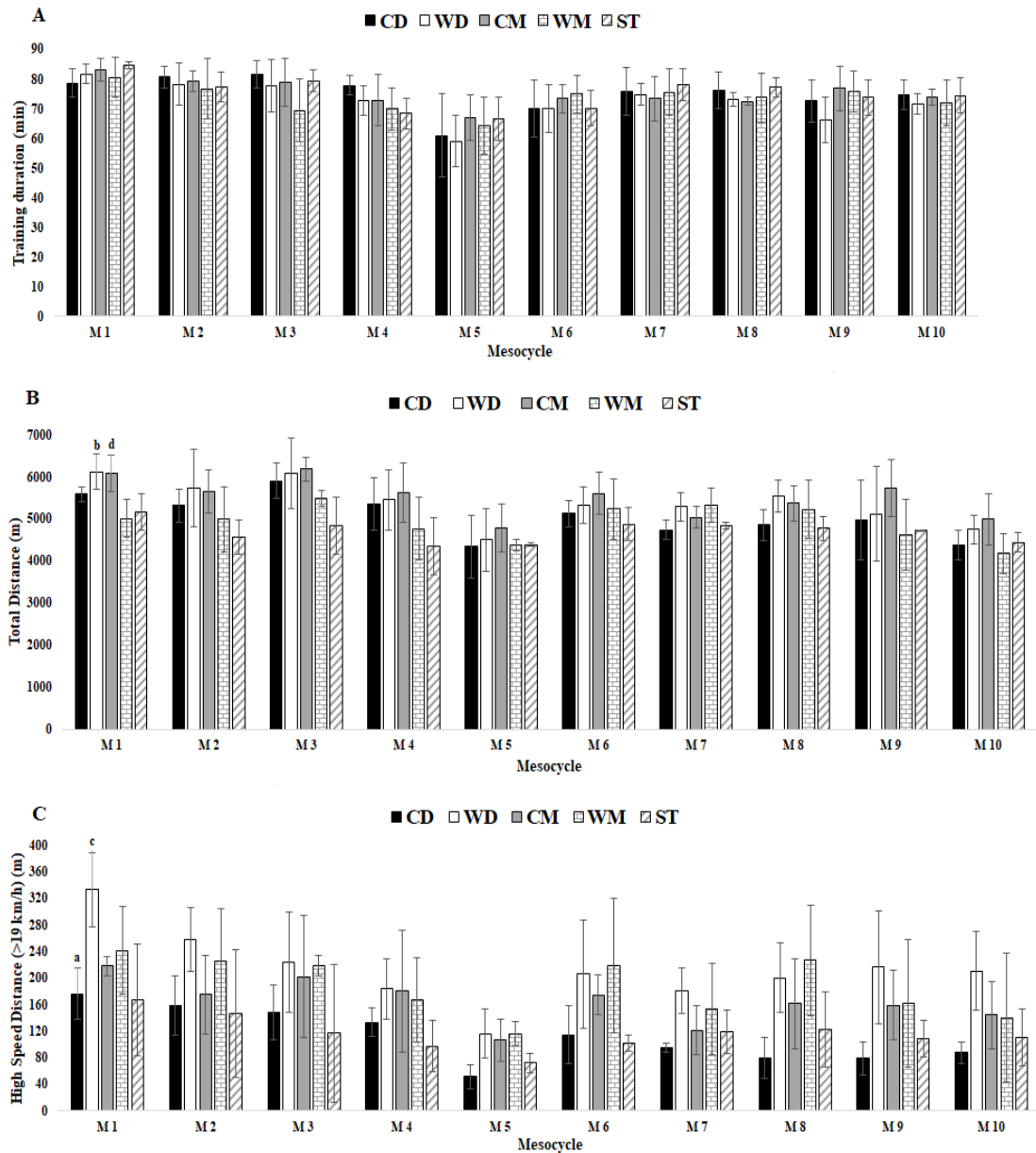


Figure 1. External TL data for training duration, total distance and HSD in respect to mesocycles between player positions.

Abbreviations: (A) training duration; (B) total distance; (C) HSD; (CD), central defenders; (WD), wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. a denotes significant difference in CD versus WD, (b) denotes significant difference in WD versus WM, (c) denotes significant difference in WD versus ST, (d) denotes significant difference CM versus WM, all $p < 0.05$.

Regarding average speed, M3 reached the highest value and M10 reached the lowest.

High-speed distance reached the highest value in M1 and lowest in M5. There were significant differences between player positions in M1 for CD vs WD (ES = 5.01 [3.02, 7.00]).

For internal load (Table 2), s-RPE was higher in M1 with a tendency to decrease until the end of the season -, M10. There were no differences between player positions during in-season (figure 2).

Table 2. Internal Training Load Data during the ten mesocycles for squad average, Mean \pm SD

Mesocycle	s-RPE (au)	Fatigue (au)	Stress (au)	Muscle Soreness (au)	Sleep quality (au)	HI (au)
M1	331.9 \pm 21.6 ^{d, g, i}	3.0 \pm 0.3	3.2 \pm 0.2	3.0 \pm 0.3	2.8 \pm 0.2	11.9 \pm 0.8
M2	287.3 \pm 22.6 ^d	3.2 \pm 0.3	3.2 \pm 0.2	3.2 \pm 0.2	2.7 \pm 0.2	12.1 \pm 0.8
M3	298.4 \pm 33.2	3.1 \pm 0.3	3.0 \pm 0.1	3.1 \pm 0.3	2.5 \pm 0.2	11.7 \pm 0.7
M4	256.9 \pm 26.6	3.4 \pm 0.2	3.0 \pm 0.2	3.3 \pm 0.2	2.9 \pm 0.3	12.6 \pm 0.7
M5	208.6 \pm 25.9	3.6 \pm 0.2	3.2 \pm 0.2 ^{i, *}	3.4 \pm 0.3	2.8 \pm 0.3	13.0 \pm 0.7 ^{i, *}
M6	250.5 \pm 22.1	3.3 \pm 0.3	2.8 \pm 0.2	3.1 \pm 0.3	2.2 \pm 0.2	11.4 \pm 0.9
M7	247.8 \pm 20.4	3.2 \pm 0.4	3.0 \pm 0.3	3.1 \pm 0.4	2.4 \pm 0.2	11.6 \pm 1.1
M8	239.8 \pm 25.8	2.9 \pm 0.3	2.5 \pm 0.2	2.8 \pm 0.3	2.4 \pm 0.3	10.6 \pm 0.8
M9	240.8 \pm 25.5	3.0 \pm 0.3	2.7 \pm 0.2	2.8 \pm 0.4	2.3 \pm 0.2	10.8 \pm 0.8
M10	239.3 \pm 26.7	3.0 \pm 0.4	2.4 \pm 0.3	2.6 \pm 0.3	2.3 \pm 0.3	10.2 \pm 0.9

M= mesocycle (1, 2, 3, etc.); s-RPE= session rating of perceived effort; HI = Hooper index; au=arbitrary units. a denotes difference from M2, b denotes difference from M3, c denotes difference from M4, d denotes difference from M5, e denotes difference from M6, f denotes difference from M7, g denotes difference from M8, h denotes difference from M9, i denotes difference from M10, all $p < 0.05$, * very large effect.

HI had fewer variations during the in-season, reaching the highest value in M5 and the lowest value in M10. Also, Stress category revealed the same results between M5 and M10. There were no significant differences between player positions for HI scores (figure 2).

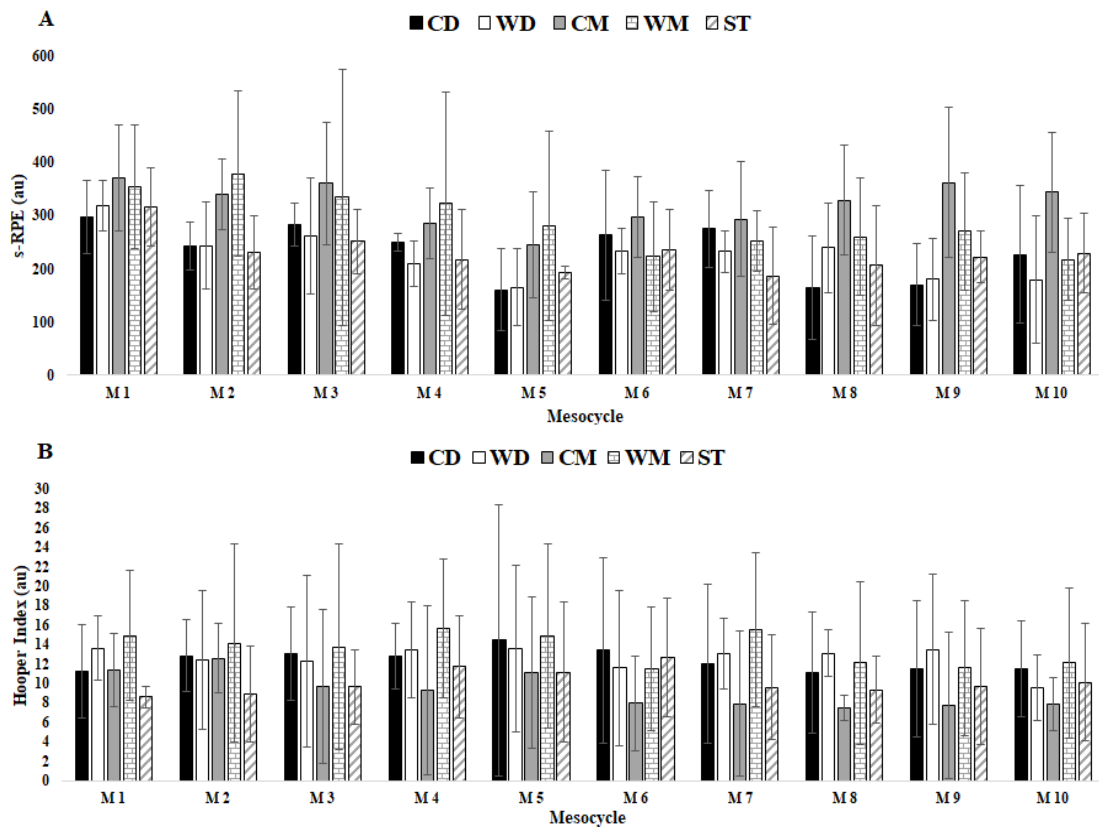


Figure 2. Internal TL data s-RPE and HI in respect to mesocycles between player positions.

Abbreviations: (A) s-RPE; (B) HI; (CD), central defenders; (WD), wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. a denotes significant difference in CD versus WD, (b) denotes significant difference in WD versus WM, (c) denotes significant difference in WD versus ST, (d) denotes significant difference CM versus WM, all $p < 0.05$.

There were associations between HI scores and s-RPE, HI scores and external TL variables, and s-RPE and external TL variables, but few correlations were found: stress and total distance in M2 (-0.634 , $p < 0.01$); fatigue and s-RPE in M9 (0.589 , $p < 0.05$); muscle soreness and s-RPE in M9 (0.487 , $p < 0.05$); fatigue and s-RPE in M11 (0.469 , $p < 0.05$); and HI total score and total distance in M11 (0.489 , $p < 0.05$).

In-Season Match-Day-Minus Training Comparison

The duration of training sessions (Table 3) in MD-1 and MD-5 was the second highest was the highest. MD+1 presented the lowest training duration. No differences were found between players positions (figure 3).

Table 3. External Training Load Data during the MD minus for squad average, Mean \pm SD

MD	Duration (min)	Total Distance (m)	Average speed (m/min)	HSD (m)
MD-5 (n=24)	80.2 \pm 1.3 ^{b, c, d, e, *}	7482.0 \pm 173.1 ^{a, b, c, d, e, *}	94.1 \pm 3.0 ^{a, c, d, e, *}	274.8 \pm 26.0 ^{c, d, e, *}
MD-4 (n=20)	74.2 \pm 1.4 ^{d, e, *}	5943.9 \pm 105.4 ^{c, d, e, *}	80.4 \pm 1.2 ^{c, d, e, *}	249.3 \pm 16.3 ^{c, d, e, *}
MD-3 (n=24)	72.8 \pm 1.3 ^{d, e, *}	6205.6 \pm 106.4 ^{c, d, e, *}	85.3 \pm 1.3 ^{c, d, e, *}	219.7 \pm 13.7 ^{c, d, e, *}
MD-2 (n=24)	73.2 \pm 0.8 ^{d, e, *}	5404.7 \pm 59.2 ^{d, e, *}	73.9 \pm 0.8 ^{d, e, *}	190.4 \pm 11.1 ^{d, e, *}
MD-1 (n=24)	86.1 \pm 0.2 ^{e, *}	3564.7 \pm 55.6 ^{e, *}	41.4 \pm 0.6 ^{e, *}	72.4 \pm 5.7 ^{e, *}
MD+1 (n=20)	20.4 \pm 1.5	4576.7 \pm 184.8	243.8 \pm 16.4	117.8 \pm 17.8

MD-=matchday minus (5. 4. 3. 2. 1); MD+1= matchday plus 1; min= minutes; m=meters; HSD = high-speed distance. a denotes difference from MD-4. b denotes difference from MD-3. c denotes difference from MD-2. d denotes difference from MD-1. e denotes difference from MD+1. all $p < 0.01$, * very large effect.

For external load, total distance reached the highest value in MD-5 and the lowest in MD-1. Regarding player positions (figure 3), there were significant differences in MD-2 between WD vs ST (5.13 [9.19, 1.07]) and CM vs ST (5.01 [9.01, 1.02]).

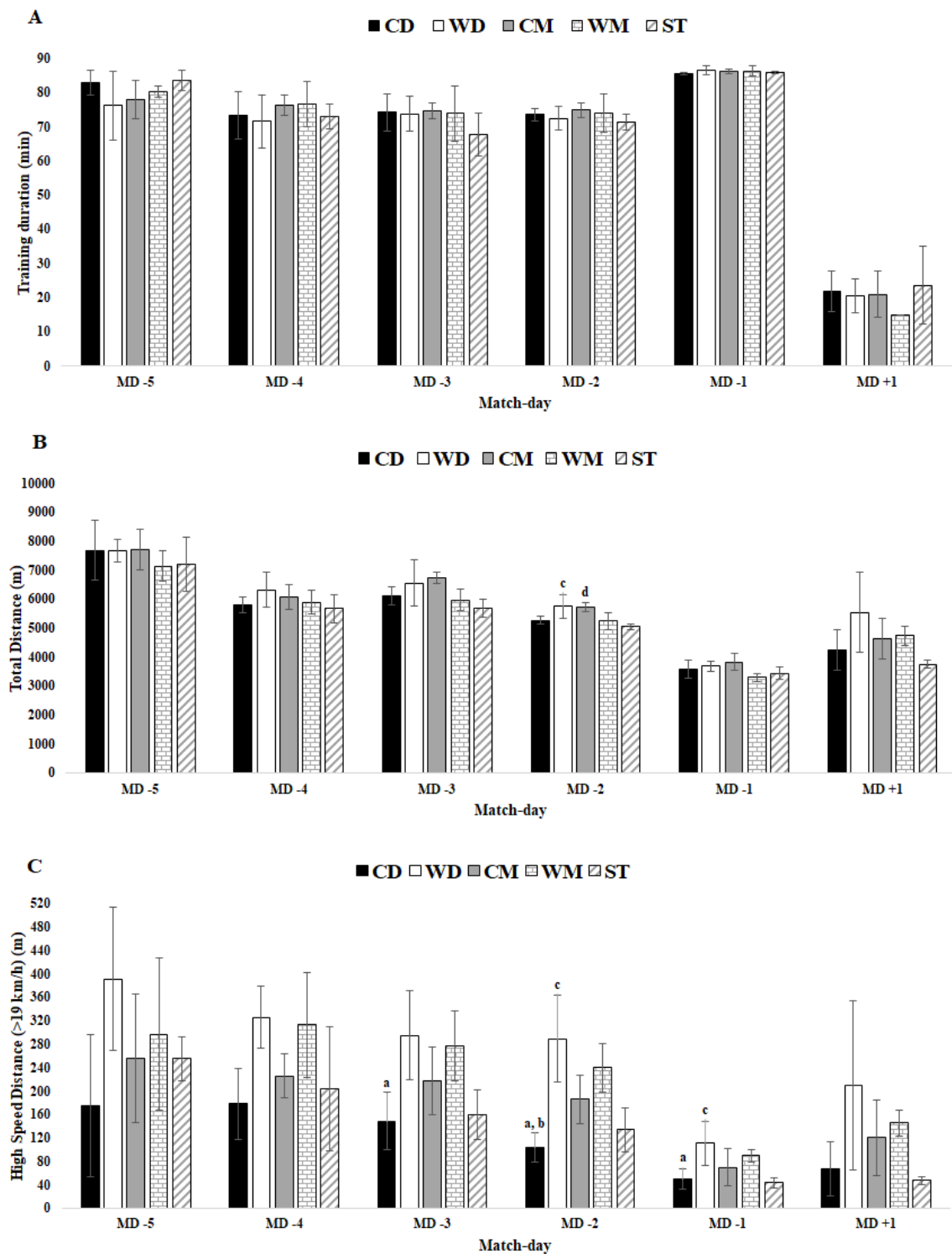


Figure 3. External TL data for training duration, total distance and HSD in respect to days before a competitive match between player positions.

Abbreviations: A) training duration; (B) total distance; (C) HSD; (CD), central defenders; (WD), wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. (a) denotes significant difference in CD versus WD, (b) denotes significant difference in CD versus WD, (c) denotes significant difference in WD versus CD.

Average speed reached the highest value in MD-5 and the lowest in MD-1. No differences were found between player positions (figure 2).

High-speed distance reached the highest value in MD-5 and the lowest in MD-1. In MD-3 there were significant differences between player positions (fig 2) for CB vs WD (4.94 [1.01, 8.89]).

In MD-2 there were significant differences between CD vs WD (7.81 [2.05, 13.57]), CD vs WM (5.74 [1.31, 10.17]) and WD vs ST (6.02 [10.62, 1.41]). In MD-1 there were significant differences between CD vs WD (4.93 [0.99, 8.86]) and WD vs ST (5.03 [1.03, 9.04]).

For internal load (Table 4), s-RPE reached the highest value in MD-3 and revealed a tendency to decrease until MD-1. The lowest were found in MD+1. No differences were found between player position (figure 4).

Table 4. Internal Training Load Data during the MD minus for squad average, Mean \pm SD

MD	s-RPE (au)	Fatigue (au)	Stress (au)	Muscle Soreness (au)	Sleep quality (au)	HI (au)
MD-5	331.7 \pm 27.0 ^{d, e, **}	3.1 \pm 0.8 ^{e, **}	2.3 \pm 0.2 ^{e, **}	2.9 \pm 0.6 ^{e, **}	1.9 \pm 0.9 ^{a,b,c,d,e}	10.2 \pm 0.7 ^{e, **}
MD-4	334.4 \pm 25.8 ^{c, d, e, **}	2.9 \pm 0.6 ^{e, **}	2.9 \pm 0.7 ^{e, *}	2.8 \pm 0.6 ^{e, **}	2.6 \pm 0.5 ^{**}	11.1 \pm 0.6 ^{e, **}
MD-3	342.4 \pm 25.3 ^{d, e, **}	2.8 \pm 0.6 ^{e, **}	2.9 \pm 0.6 ^{e, **}	2.9 \pm 0.5 ^{e, **}	2.5 \pm 0.6 [*]	11.1 \pm 0.6 ^{e, **}
MD-2	274.3 \pm 23.2 ^{d, e, **}	3.0 \pm 0.5 ^{e, **}	2.7 \pm 0.6 ^{e, **}	3.0 \pm 0.6 ^{e, **}	2.6 \pm 0.7 [*]	11.3 \pm 0.6 ^{e, **}
MD-1	212.3 \pm 15.5 ^{e, **}	2.9 \pm 0.6 ^{e, **}	2.6 \pm 0.6 ^{e, **}	2.9 \pm 0.6 ^{e, **}	2.5 \pm 0.6 [*]	10.9 \pm 0.6 ^{e, **}
MD+1	33.6 \pm 3.7	4.4 \pm 0.7	3.9 \pm 0.2	4.4 \pm 0.7	2.7 \pm 0.9 [*]	15.4 \pm 0.7

MD-=matchday minus (5. 4. 3. 2. 1); MD+1= matchday plus 1; s-RPE = session rating of perceived effort; HI = Hooper index; au=arbitrary units. a denotes difference from MD-4. b denotes difference from MD-3. c denotes difference from MD-2. d denotes difference from MD-1. e denotes difference from MD+1. all $p < 0.01$, * large effect, ** very large effect.

HI and all categories had few variations during the MD minus with the exception of MD+1 where the highest values were found. No differences were found between player positions (figure 4).

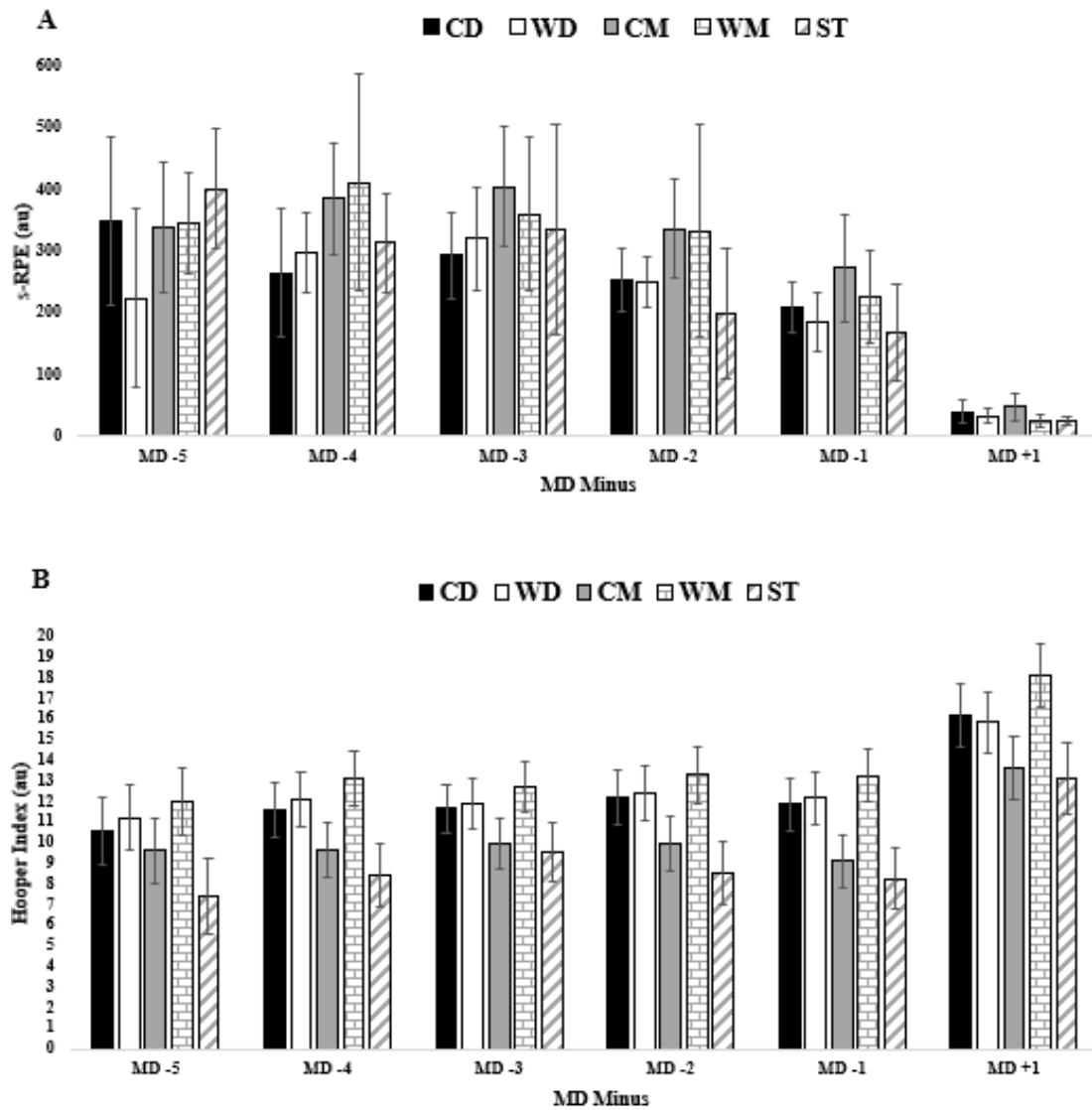


Figure 4. Internal TL data for s-RPE and HI in respect to days before a competitive match between player positions.

Abbreviations: A) s-RPE; (B) HI; (CD), central defenders; (WD), wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers.

Discussion

The purpose of the present study was to quantify the internal and external TL carried out by an elite soccer team during the in-season (10 mesocycles). The main findings of the study are related to similar training load during in-season, but HSD and s-RPE were higher in the first mesocycle. Also, external TL decrease from MD-5 until MD-1 while internal TL variables did not present the same pattern. In addition, HI remained constant for all mesocycle and training sessions with the exception for the following day of the match, which exhibit higher value.

In-season mesocycle analysis

For external TL variables, it was observed that the players covered a greater total distance at the start (M1 and M3) compared to the final mesocycle (M10) of the in-season, with an estimated difference of 1044 m and 1146 m, respectively. The higher distances covered at the beginning of the in-season may be due to the coaches still having some emphasis on physical conditioning immediately after the pre-season. In addition, the lower values in distance covered for M10 could be associated with the in-season ending and consequently a reduction in external TL.

According to Alexiou & Coutts (2008) and Impellizzeri et al. (2004), and the competitive matches represent the greatest TL that soccer players typically experience. In addition, Los Arcos, Mendez-Villanueva and Martínez-Santos (2017) and Malone et al. (2015) reported that total distance values were significantly higher at the start of the annual in-season compared to the final stage 1304 (434 - 2174) m, ES = 0.84 (0.28 - 1.39) and (ES = from - 0.56 to -1.20), respectively. These previous data corroborate our results because it was possible to observe higher values in M1 compared to M10, although M5 had the lowest values for total distance (table 1).

The present data suggest that in-season variability in TL is very limited and only minor decrements in TL across the in-season might occur. Apparently, this TL maintenance during the in-season could be associated with the importance of the recovery activities after the matches and the decisions made to reduce TL until the next match (Moreira et al., 2015). Furthermore, elite European soccer teams training programmes remain constant during all mesocycles of the in-season and corroborate the suggestion made by Malone et al. (2015) because there is a need to win matches that does not allow the reaching of a specific peak for strength and conditioning.

The average total distance covered was 5111 m (4473-5691 m) which was similar to the 5181 m value reported by Malone et al. (2015) and slightly higher than those reported by Gaudino et al. (2013) (3618-4133 m). However, both the distances covered in the present study and in Gaudino et al. (2013) study fell short in comparison to those reported by Owen et al. (2016) (6871 m) because their study only included data from training sessions. This means that the study conducted by Owen et al. (2016) reported higher distances covered even with lower training sessions. In terms of high-speed distance, the values (average 118 m) fall within the range of that of Gaudino et al. (2013) (88-137 m) across different positions.

The results indicate that TL variables demonstrated limited relevant variation between player positions (see figure 1 and 2). It seems that competitive matches have been quantified as the most demanding session (i.e. greatest TL) of the week (Bradley et al., 2009; Los Arcos et al., 2017; Moreira et al., 2015; Oliveira et al., 2019; Stevens et al., 2017). Previous work corroborated this statement, although player position was not analysed (Oliveira et al., 2019). For instance, Di Salvo et al. (2007) reported that CM generally cover more distances compared

to other positions during competitive matches. This result corroborates the current results because CM (5502 m) covered more total distance than CD (5052 m), WD (5388 m), WM (4918 m) or ST (4694 m), but without statistical significance. In addition, when we compared the distance covered in high-speed running (≥ 19 km/h) during in-season mesocycle analysis to positions played, a significant difference was found between positions only for M1 when comparing CD vs WD and WD vs WM. There was no other difference between player positions in all mesocycles (figure 1). These results suggest that the WD (212.7 m) and WM (186.8 m) positions resulted in higher effort (> 19 km/h) during training when compared to all other positions (CD = 112.2, CM = 164.1, ST = 116.1 m). Further, every position saw similar efforts at low speed distance (CD = 4563.7; WD = 4724.5, CM = 4767.8, WM = 4340.4, ST = 4233.3 m) which is in opposition to other studies (Bradley et al., 2009; Di Salvo et al., 2007; Di Salvo, Gregson, Atkinson, Tordoff & Drust, 2009).

Regarding internal TL, the s-RPE response was higher in M1 (331 arbitrary units (au)) in comparison to the last mesocycle (M10, 239 au) which is in line with data from external TL total distance and HSD variables. However, it is relevant to consider that this also was the mesocycle with higher training duration. Furthermore, it was found that in the middle of the season (M5) there was a lower response (208 au) for this parameter. This finding could be associated with some interruption for TL carried out during training sessions due to the Christmas period and with an increase in the number of matches played in M5 (6 matches). In general, there were no differences between player positions (see figure 1). Therefore, it appears that there is no marked variation in internal TL across 10 mesocycles during the in-season. Some studies (Clemente et al., 2017; Malone et al., 2015, 2018; Morgans et al., 2014) have also reported the limited relevant variation in TL across the in-season. This seems to suggest that professional soccer daily training practices follow a regular load pattern because they are linked to higher congestive periods of matches. Furthermore, the importance of the recovery activities following matches and the decisions made to reduce TL between matches to prevent fatigue during this period can also play an important role in this constant TL (Moreira et al., 2015).

Moreover, the data provides relevant information to quantify internal TL, measured by s-RPE during microcycles and mesocycles. This may provide relevant information to establish guidelines for soccer training periodization. The average of s-RPE during microcycles TL was 254.8 au (range 33-342 au). These values are lower than those reported by Scott et al. (2013) (297 au: range 38-936 au), but similar to Jeong, Reilly, Morton, Bae and Drust (2011) study: 174-365 au. for elite Korean soccer players. The s-RPE values were also lower than the 462 au of semi-professional soccer players reported by Casamichana et al. (2013). Another explanation for the lower values could be related to the number of matches during each week and amongst mesocycles. It should be reemphasised that we studied a top-class elite professional European soccer team. The range of s-RPE for mesocycles of the in-season was 208-331 au. Overall it would appear that in comparison to top elite soccer players, the internal TL employed by our

study falls within the boundaries of what has been previously observed (Casamichana et al., 2013; Jeong et al., 2011; Scott et al., 2013).

Haddad et al. (2013) suggested that s-RPE is not sensitive to the subjective perception of fatigue, muscle soreness or stress levels. In contrast, however, Clemente et al. (2017) stated that s-RPE could be a reliable tool to quantify the internal TL and therefore could be a good indicator for coaches and for practical applications in team sports training. Data presented in the current experiment seems to corroborate this statement, indicating that s-RPE can be an effective tool to measure the intensity and duration of training session in elite European soccer teams. On this subject, some studies have stated that RPE may be a physiological and volatile construct that could be different according to the cognitive focus of the player (Ferraz et al., 2017, 2018; Renfree, Martin, Micklewright & Gibson, 2014). Nevertheless, Renfree et al. (2014) reported that RPE can be dissociated from the physiological process through a variety of psychological mechanisms. Therefore, RPE could be an oversimplification of the psychophysiological perceived exertion and a non-conclusive measure for capturing a wide range of sensations experience (Castellano, Alvarez-Pastor & Bradley, 2014; Ferraz et al., 2017, 2018). Another major point is that RPE was collected 30 min after the end of each training session and it would be pertinent to check if there is some variation during the training session, as contended by Ferraz et al. (2018). These arguments may justify the fact that there were no differences in s-RPE between training days as well as the absence of a relationship with the external TL results.

HI remained similar during 10 mesocycles. In addition, comparing player positions, there were no differences for HI scores; this was not supported by Clemente et al. (2017) although their study was based on data from one vs two-matches week ($p < 0.05$). To the best of our knowledge, this is the first study to analyse HI scores during an entire in-season. Clemente et al. (2017) showed that central defenders (12.46 ± 2.54) and wide midfielder (12.42 ± 3.44) had higher values of HI scores than strikers (12.18 ± 4.84) and wide defenders (12.16 ± 3.04). Centre midfielders had the lowest HI scores (10.34 ± 3.87). Despite these, the authors found several significant differences between positions but, in general, these values were small. A possible explanation for these non-consensual results could be associated with the differences in soccer TL.

In soccer training, due to the extensive use of small-sided matches and the different physical (e.g. running) requirements associated with each position (Castellano et al., 2014; Di Salvo et al., 2007; Rampinini et al., 2007), training demands can be markedly different between individuals (Impellizzeri et al., 2005; Los Arcos, Martinez-Santos, Yanci, Mendiguchia & Mendez-Villanueva, 2015; Manzi, Bovenzi, Impellizzeri, Carminati & Castagna, 2013). This hypothetical difference in TL could be amplified considering that only 11 players can start each official match, and therefore a considerable number of players per team are not exposed to the TL of the match.

As suggested by Clemente et al. (2017) study, we also correlated HI scores with s-RPE and external TL variables, and some correlations could be observed: stress and total distance in M1 (-6.34, $p < 0.01$); fatigue and s-RPE in M8 (0.589, $p < 0.05$); muscle soreness and s-RPE in M8 (0.487, $p < 0.05$); fatigue and s-RPE in M10 (0.469, $p < 0.05$); and HI total score and total distance in M10 (0.489, $p < 0.05$). These results are not in line with the literature, which suggests non-significant correlations ($r = 0.20$) between s-RPE and perceived quality of sleep (from the Hooper questionnaire) (Clemente et al., 2017; Moalla et al., 2016). However, Thorpe et al. (2015) reported associations between s-RPE and perceived fatigue, but not with perceived quality of sleep. It is important to note that this last study analysed data for short periods of training (microcycles). Therefore, since our study also comprised longer periods of training, we can assume that this could have influenced the current results.

In-season match-day-minus training comparison

In the present study, we also investigated the TL pattern in respect to number of days prior to a one- match week during the in-season phase.

For external TL, our data provided the following pattern by decreasing values from until MD-1: MD-5 > MD-4 < MD-3 > MD-2 > MD-1 for total distance and average speed, MD-5 > MD-4 > MD-3 > MD-2 > MD-1 for HSD (table 2). Our results are not in line with elite English Premier League players for total distance and average speed, where it was found a lowering of the load only in MD-1 (Malone et al., 2015).

We also observed a noticeable consistent variation in external TL, total distance covered, in MD-1 when the load was significantly reduced in comparison with the rest of the training days. Our data corroborates with some studies (Akenhead et al., 2016; Malone et al., 2015; Thorpe et al., 2015).

Finally, MD+1 revealed significant result despite the limited training duration (~20 min). The average speed and HSD has higher values than all other match days minus. One argument that can justify these results could be the high-intensity applied by the coach (which was not controlled in this study). Another explanation is related to the context, competitive schedule and the objectives defined for TL management, once MD+1 had little duration (20 min). Another possible justification could be associated with a training session of recuperation with lower load for starters and a “normal” training session for non-starters.

When we compared HSD (above 19 Km/h) during in-season match-day-minus by positions, a significant difference was found between positions when comparing WD vs ST and CD vs WD, CD vs WM in MD-2 in MD-2. In addition, when we compared total distance covered, a significant difference could be observed between CD (149 m) vs WD (295 m) in MD-3, CD (103 m) vs WD (289 m) in MD-2 and CD (49 m) vs WD (111 m) in MD-1; CD (103 m) vs WM (240 m), WD (289 m)

vs ST (134 m) in MD-2; and also WD (111 m) vs ST (43 m) in MD-1 (figure 2). These results are in line with other studies (Bradley et al., 2009; Di Salvo et al., 2007, 2009; Jeong et al., 2011) that reported that CM players have consistently been found to cover more distance in general while WM players cover more distances at high-intensity running speed.

Regarding match days, Reilly & Thomas (1976) and Rienzi, Drust, Reilly, Carter and Martin (2000) stated that higher distances are covered by midfield players (11.5 km); however, Bangsbo (1994) reported that elite defenders and strikers covered approximately the same distance (10-10.5 km). This may be due to the nature and role of the position inside the team, as well as coaching strategy and/or game plan. During training sessions, the coach or the conditioning staff may find it advantageous to model training to elicit similar effort or experience the same training load regardless of position.

For internal TL, s-RPE data presented a non-perfect pattern by decreasing values from until MD-1: MD-5 < MD-4 < MD-3 > MD-2 > MD-1 for s-RPE (table 2), but none between player positions (fig 2). We also observed a noticeable consistent variation in s-RPE on MD-1 in elite soccer players, when the load was significantly reduced in comparison with the rest of the training days (Akenhead et al., 2016; Malone et al., 2015; Thorpe et al., 2015). In addition, the data presented by s-RPE is associated with external TL variation.

Furthermore, HI scores revealed no variation in days prior to the match. These results are in line with those reported by Haddad et al. (2013), where it was suggested that fatigue, stress, muscle soreness and sleep are not major contributors of perceived exertion during traditional soccer training without excessive TL. Our results also do not support Hooper and Mackinnon (1995) study because self-reported ranking of well-being does not allow the provision of efficient mean of monitoring internal TL. In fact, the only exception was sleep quality category which revealed the lowest value and therefore bad sleep quality in MD-5. This higher value could be associated to the stimulus imposed by the previous match. It is relevant to remember that microcycles had different week-patterns and consequently, MD-5 could also be related to the following day of the match.

In opposition to the results presented for external in MD+1, internal TL, s-RPE has a lower value than all other match days (33.6 au) but HI has a higher value than all other match days (15 au) (table 1). These results are associated with an accumulative high-intensity training session between MD-5 and MD-2 and also supports the claim that matches represent the most demanding workload of each week (Bradley et al., 2009; Los Arcos, Yanci, Mendiguchia & Gorostiaga, 2014; Los Arcos et al., 2017; Oliveira et al., 2019; Stevens et al., 2017).

Practical Applications and Limitations

This study provides useful information relating to the TL employed by an elite European soccer team that played in a European Competition. It provides further evidence of the value of using the combination of different measures of TL to fully evaluate the patterns observed across the in-season. For coaches and practitioners, the study generates reference values for elite players which can be considered when planning training sessions. However, it is important to remember that the in-season match-day-minus training comparison was analysed by mean values and microcycles/weeks (7-day period) of the in-season have different patterns, as mentioned before. Another limitation is related to the numerous true data points missing across the 39-week data collection period due to several external factors beyond our control (e.g. technical issues with equipment, player injuries, and player transfers). Finally, GPS technology used in this study does not allow to report the horizontal dilution of precision and for that reason the findings regarding external TL need to be interpreted considering such a limitation as stated in Beato et al. (2018).

Conclusions

In summary, we provide the first report across 10 mesocycles of an in-season that included HI scores and s-RPE to measure internal TL plus distances covered at different intensities measured by GPS, in elite soccer players that played European competitions. Our results reveal that although there are some significant differences between mesocycles, there was minor variation across the season for the internal and external TL variables used. In addition, it was observed that MD-1 presented a reduction of external TL during in-season match-day-minus training comparison (regardless of mesocycle) (i.e. reduction of total distance, HSD and AvS) and internal TL (s-RPE). However, the internal TL variable, HI did not change, except for MD+1. This study also provided ranges of values for different external and internal variables that can be used for other elite teams.

Study 2

In-season training load quantification of one-, two- and three-game week schedules in a top European professional soccer team

Abstract

Top European soccer teams that play in Union of European Football Associations (UEFA) competitions often participate in one, two- or three-games per week. Therefore, it is necessary to ensure optimal match-day performance and full recovery. The aim of this study was to quantify internal and external TLs within five microcycles: M1 and M2 - one-game weeks; M3 and M4 - two-game weeks; M5 - three-game week). Thirteen elite soccer players participated in this study. A global positioning system (GPS) was used to measure the total distance covered and distances of different exercise training zones (1-5), the session ratings of perceived exertion (s-RPE) scores and the amount of creatine kinase (CK) created during daily training sessions for the 2015-2016 in-season period. The data were analysed with respect to the number of days prior to a given match. The main results indicate a significant difference in training intensity for zone 1 between M2 and M4 (4010.2 ± 103.5 and 4507.6 ± 133.0 meters (m), respectively); a significant difference in training intensity for zone 3 between M1 and M5 (686.1 ± 42.8 and 801.2 ± 61.2 m, respectively); a significant difference in the duration of the training sessions and matches between M2 and M5 (69.2 ± 2.1 and 79.6 ± 2.3 m) and M3 and M5 (69.7 ± 1.0 and 79.6 ± 2.3 m); and finally, there was a significant difference in CK between M3 and M2 (325.5 ± 155.0 and 194.4 ± 48.9 m). Moreover, there was a significant decrease in TL in the last day prior to a match, for all microcycles and all variables. There was no significant difference with respect to s-RPE. This study provides the first report of daily external and internal TLs and weekly accumulated load (training sessions and match demands) during one, two, and three-game week schedules in a group of elite soccer players. Expected significant differences are found in daily and accumulated loads for within- and between-game schedules. A similar pattern is exhibited for one- and two-game week microcycles regarding the day before the match, which exhibits a decrease in all variables. Despite the different number of games played per week, TL remain similar between microcycles for zone 2 and 5, plus s-RPE.

Keywords: Soccer Training; Internal Load; External Load; Training Load; Periodization; GPS.

Introduction

Generally, in soccer, games occur once every week. However, teams that play in Union of European Football Associations (UEFA) competitions and domestic league/cup competitions may participate in more games (two or three) per week (Anderson et al., 2016; Morgans, Adams, Mullen, McLellan & Williams, 2014; Thorpe et al., 2016). More games per week, and thus more games per season, can make it difficult for coaches to manage the training load (TL) and avoid accumulated fatigue, while ensuring that players remain at an optimal level of physical fitness. In fact, the inappropriate management of TL has quickly become one of the main risk factors in non-contact injuries (Jones, Griffiths & mellalieu, 2017; Soligard et al., 2016) or increased levels of fatigue, as well as higher risk of illness (Jones et al., 2017). Quantifying and comparing the TL experienced during microcycles with different number of games could help explain the changes between microcycles throughout the in-season. Therefore, it is very important to monitor TL to ensure optimal match-day performance and recovery (Morgans et al., 2014; Nédélec et al., 2012) and, consequently, it would be expected a proper training periodization to maximize physiological adaptations and technical/tactical performances. However, the application of classic training periodization is limited for elite European soccer teams due to congestive periods of soccer matches. For instance, elite European players may only participate in 1-2 training sessions between two matches. Consequently, coaches spent some time on recovery training sessions during the in-season. In fact, only recently the scientific community tried to describe the in-season training periodization practices of elite soccer teams in more detail, including a comparison of training days within weekly microcycles (Akenhead, Harley & Tweddle, 2016; Anderson et al., 2016; Malone et al., 2015).

TL includes both external and internal loads. External TL is associated with the physical work performed during a training session or match (e.g., distances covered at different speeds), while internal TL is related to biochemical (psychological and physiological, e.g., rating of perceived exertion - RPE) and biochemical stress responses (e.g., creatine kinase (CK)) (Impellizzeri, Rampinini & Marcora, 2005; Vanrenterghem, Nedergaard, Robinson & Drust, 2017). By the 1970s, soccer teams were limited to the use of subjective scales to monitor TL such RPE initially developed by Borg (1970) and later adapted by Foster in the spelling words of the scale (Foster et al., 2001). Another simple time-efficient and cost-effective method of assessing TL is to multiply the total exercise duration (in minutes) by RPE (using an adapted Borg (Borg, 1970; Foster et al., 2001)), also known as the session rating of perceived exertion (s-RPE) (Foster, 1998; Foster et al., 1995, 2001; Impellizzeri, Rampinini, Coutts, Sassi & Marcora, 2004). In recent years, this method has incorporated the use of heart-rate (HR) telemetry systems, which include semi-automated multi-camera systems, local positioning systems, global positioning systems (GPS) with accelerometer, magnetometer, gyroscope, barometer. Biochemical markers have also been used to analyse the impact of internal TL. One of the most commonly used markers is CK. Indeed, CK is widely considered to be a marker of

fatigue status (Ascensão et al., 2008; Russell et al., 2015) and skeletal muscle fibre damage (Mougios, 2007). Thus, CK should be considered and analysed in addition to other TL values to clarify results (Heisterberg, Fahrenkrug, & Andersen, 2014).

Several studies have examined the soccer in-season phase, which includes short training microcycles of 1-2 weeks for top-level and elite junior players (Owen et al., 2016a,b; Wrigley, Drust, Stratton, Scott & Gregson, 2012), mesocycles of 4-10 weeks for young (Impellizzeri et al., 2004) and elite players (Gaudino et al., 2013; Scott, Lockie, Knight, Clark & Janse de Jonge, 2013) and longer training blocks of 3-4 months for professional players (Casamichana, Castellano, Calleja-Gonzalez, San Róman & Castagna, 2013). Manzi, Bovenzi, Impellizzeri, Carminati and Castagna, (2013) have attempted to quantify TL throughout the pre-season and Jeong, Reilly, Morton, Bae and Drust (2011) have conducted a comparison of TL during the pre-season and the in-season, both for professional players. However, the majority of these studies only provide limited information about TL, since they consider the duration and session of RPE and do not include any GPS data. In addition, few studies among elite soccer players (Clemente et al., 2017; Jeong et al., 2011; Manzi et al., 2013) have attempted to quantify TL with respect to changes between mesocycles and microcycles across a full competitive season. None of the studies have analysed and compared internal and external TL simultaneously across microcycles with 1-, 2- and 3-game week during the competitive soccer phase.

Furthermore, the physical demands of training on elite professional soccer players are not currently well documented and are limited to reports of a single week exposure (Malone et al., 2018). However, elite soccer players often play two (e.g. Sunday-to-Saturday) or three (e.g. Sunday-Wednesday-Saturday) games over a seven-day period. This is largely due to involvement in numerous competitions (i.e. domestic league/cup competitions and UEFA competitions) and periods of intense schedules, such as in the winter (Morgans, Orme, Andreson, Drust & Morton, 2016). Periodized or tapering approaches, which means a decrease in TL until the match, were reported within the literature have attempted to facilitate a progressive TL (Owen, Wong, Paul & Dellal, 2014) or reduce the risk of injury (Stevens, Ruiter, Twisk, Savelsbergh & Beek, 2017). Only recently sports scientists have begun to describe the in-season training periodization practices of elite soccer teams in more detail, including a comparison of training days within weekly micro-cycles (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015; Stevens et al., 2017). Malone et al. (2015) have found that only the last training session before a match differs from other training days with regard to duration, total distance, average speed and s-RPE. Moreover, Akenhead et al. (2016) have reported a similar decrease in total distance and high-speed running distances (HSRD) for training sessions closer to match-day. Nevertheless, there are limited data regarding the single-week exposure of TL in elite professional soccer players (Gaudino et al., 2013). Therefore, it is important to further examine how TL is managed on days between games for one, two and three game week schedules because weekly training

frequency is different. This information could be important for coaches and sports scientists to determine the correct approach (Smith, 2003).

Thus, the aim of this study was to quantify TL and match load for three different weekly game schedules: one-, two- and three-game week, from five different weeks, during the 2015-2016 season in a sample of elite European soccer players.

Material and methods

Participants

Thirteen elite soccer players belonging to a top European team that played in a UEFA Champions league with a mean \pm SD age, height and mass of 26.2 ± 4.1 years, 183.5 ± 6.1 cm and 78.7 ± 5.1 kg, respectively, participated in this study. The participating players consisted of two central defenders (CD), two wide defenders (WD), five central midfielders (CM), two wide midfielders (WM) and two strikers (ST). We adapted inclusive criteria from Stevens et al. (2017) using the records of players who played for at least 60 minutes (min) on a UEFA Champions league game, or a national league game or a national cup in each of the three-week pattern microcycles. There was a drop-out of 24 players due to the lack of collected data in the chosen weeks. All participants were familiarised with the training protocols prior to investigation. This study was conducted according to the requirements of the Declaration of Helsinki and was approved by the institution's research ethics committee.

Design

For this longitudinal study, training and match load data were collected over a 39-week period during the 2015-2016 annual season (July 2015 to May 2016). The team used for data collection competed in four official competitions across the season, including the UEFA Champions league, the national league and two more national cups from their own country, which often meant that the team played one, two or three games per week. For the purposes of the present study, all sessions conducted during the main team sessions were considered. Moreover, all data collected from matches for the period chosen were considered. Only data collected from the training sessions and the matches of players who played for at least a minimum of 60 min on each microcycle, was considered. Data from rehabilitation or recuperation was excluded. The duration of the training sessions includes the warm-up, main and slow-down phases, plus stretching. All training programs were planned by the coach and staff and the researchers only standardized the first 30 min and the final 30 min (i.e. before and after each training session). The familiarization of the subjective scale session-RPE was held during the pre-season period.

The weeks were chosen based on the number of games played (one, two, or three), in addition to the inclusion of four training sessions within the week, following one or two days off for recovery and one or two in-house recovery sessions (Table 1).

Table 1. Weekly training for microcycles with one-, two- and three-games week.

M1 and M2, one-game week						
Day 1 (MD+1)	Day 2 (MD-5)	Day 3 (MD-4)	Day 4 (MD-3)	Day 5 (MD-2)	Day 6 (MD-1)	Day 7 (MD)
day-off	day-off	training session	training session	training session	training session	MD
M3, two-games week						
Day 1 (MD)	Day 2 (MD+1)	Day 3 (MD-4)	Day 4 (MD-3)	Day 5 (MD-2)	Day 6 (MD-1)	Day 7 (MD)
MD	day-off	training session	training session	training session	training session	MD
M4, two-games week						
Day 1 (MD)	Day 2 (MD+1)	Day 3 (MD-3)	Day 4 (MD-2)	Day 5 (MD-1)	Day 6 (MD)	Day 7 (MD+1)
MD	training session	training session	training session	training session	MD	day-off
M5, three-games week						
Day 1 (MD)	Day 2 (MD-2)	Day 3 (MD-1)	Day 4 (MD)	Day 5 (MD-2)	Day 6 (MD-1)	Day 7 (MD)
MD	training session	training session	MD	training session	training session	MD

Abbreviations MD- = matchday minus (5, 4, 3, 2, 1); MD+1 = matchday plus 1.

Total minutes of the matches did not include time spent warming up before a match. Although compensation minutes were included in the collected data, this number is not given because the administration of the soccer club does not want to any information disclosed that could reveal which team was studied.

Experimental Procedures

Training and match data were collected over the course of five different 7-day periods (microcycles): for one-game week, microcycle M1 against one medium/bottom-level opponent and M2 against one top-level opponent from the national league; for two-game week, microcycle M3 against a top-level opponent from the European Champions league and a medium/bottom-level opponent from the national league, plus microcycle M4 against two medium/bottom-level opponents from two national leagues; for three-game week, microcycle M5 against medium/bottom-level opponents from the national league, national cup league and national league, respectively. Although other weeks also fit the descriptions provided, the five different weeks selected met the criteria for participants, meaning that they completed all training sessions during the chosen weeks and completed at least one game during the timeframe. A total number of 20 training sessions (260 individual) and 9 games (117 individual) were observed for this study. This study did not influence or alter the training sessions in any

way. Training and match data were collected at the soccer club's outdoor training pitches. The data were analysed in relation to the day of the weekly microcycle (i.e. day 1, day 2... and day 7). Moreover, we also included the "match day minus" approach used by Malone et al. (2015) to increase clarity with regard to the different weekly scenarios.

External training load - training data

Each player's physical activity during each training session was monitored using a portable GP unit (Viper pod 2, STATSports, Belfast, UK). Research has shown this system to be a valid and reliable marker of assessment for monitoring a team player's movements (Jennings, Cormack, Coutts, Boyd, Aughey, 2010a). This device provides position velocity and distance data at 10 Hz. Each unit includes a GPS sensor (10 Hz) which logged coordinates at 1Hz coupled with three axes of acceleration, which measured up to +/- 8g, and logged data at 100 Hz. Each player wore the device inside a custom-made vest across the upper back, between the left and right scapula. In this position, the GPS antenna is exposed to allow for clear satellite reception. This type of system has previously been found to provide valid and reliable estimates of instantaneous and constant velocity movements during linear, multidirectional and soccer-specific activities (Castellano, Blanco-Villaseñor & Alvarez, 2011; Coutts & Duffield, 2010). All devices were activated 30 min before data collection to allow for the acquisition of satellite signals and to ensure that the GPS clock was synchronised with the satellite's atomic clock (Maddison & Mhurchu, 2009). Following each training session, GPS data were downloaded using the respective software package (Viper PSA software, STATSports, Belfast, UK) and were cut to only include movements that occurred during the training session (i.e. the beginning of the warm-up to the end of the last organised drill). In order to avoid inter-unit errors, players wore the same GPS device for each training session (Buchheit, 2014; Jennings, Cormack, Coutts, Boyd & Aughey, 2010b).

Thus, the following variables were selected: total duration of training session, total distance, distance of different exercise intensity zones: zone 1 (0 - 10.9 Km/h), zone 2 (11 - 13.9 Km/h), zone 3 (14 - 18.9 Km/h), zone 4 (19 - 23.9 Km/h) and zone 5 (> 24 Km/h). The run-speed threshold categories used are in accordance with previous studies (Di Salvo, Collins, McNeill & Cardinale, 2006; Issurin, 2010).

External training load - match data

Each player's match data were examined using a tracking system (DatatracX®) to provide real-time analysis.

Thus, the following variables were selected: total duration of match, total distance, distance of different exercise intensity zones: zone 1 (0 - 10.9 Km/h), zone 2 (11 - 13.9 Km/h), zone 3 (14 - 18.9 Km/h), zone 4 (19 - 23.9 Km/h) and zone 5 (> 24 Km/h).

Internal training load - training data

Since the early development of the original Borg scale (Borg, 1970) to control rating of perceived exertion (RPE), several adaptations have been developed to allow a better way to control individual exercise intensity, such as, the 10-point scale developed by Foster et al. (2001) and the adapted Borg CR10-scale (Borg, 1970). Despite the differences in the number of points and wording within the scales, all determine an individual's internal response and/or physiological stress to an external stimulus and provide information regarding their perceived effort post-training or competition. Thirty minutes after each training session, the players were asked to provide an RPE rating, using the modified CR10-scale by Foster et al. (2001). All players were familiarized with the RPE scale prior to the commencement of the study. Players were prompted to track their RPE individually using a custom-designed application on a portable computer tablet. Each player selected their RPE rating by touching the respective score on the tablet, which was then automatically saved to the player's profile. This method helped minimise factors that could influence a player's RPE rating, such as peer pressure and replicating other players' ratings (Burgess & Drust, 2012). Each individual RPE value was multiplied by the session duration to generate a session-RPE (s-RPE) value (Foster et al., 1995, 2001; Foster, 1998).

Forty-eight hours before the matches, we measured the concentration of plasma CK found in each player (Nédélec et al., 2012). To accomplish this, the skin was first cleaned using a 95% ethyl alcohol. After drying, 32 µL of capillary blood was collected using an automatic lancet. The blood was saved in a heparinized capillary tube (Reflotron Plus, Roche Diagnostics) and immediately pipetted onto a reactive CK strip (Reflotron Plus, Roche Diagnostics), to be placed in a Boehringer Mannheim Reflotron Analyser®.

Statistical Analysis

Data were analysed using the SPSS version 22.0 (SPSS Inc., Chicago, IL) for Windows statistical software package. Initially, descriptive statistics were used to characterize the sample. Shapiro-Wilk and Levene tests were conducted to determine normality and homoscedasticity, respectively. Once variables obtained a normal distribution (Shapiro-Wilk > 0.05), it was used a repeated measures ANOVA test and the Bonferroni post-hoc test to determine where the specific differences lay. And to compare variables for each of the seven days of the week. This process was repeated to also allow a comparison between all microcycles/weeks. The results are significant for a $p \leq 0.05$. The effect-size (ES) statistic was calculated to determine the magnitude of effects by standardizing the coefficients according to the appropriate between-subjects standard deviation and was assessed using the following criteria: < 0.2 = trivial, 0.2 to 0.6 = small effect, 0.6 to 1.2 = moderate effect, 1.2 to 2.0 = large effect, and > 2.0 = very large (Hopkins, Marshall, Batterham & Hanin, 2009).

Results

Day-to-day variations in TL across one-, two and three-game weeks

Duration of activity and distance covered within specific speed zones are presented in Tables 2 and 3, respectively. In addition to the global indices of training and match load, the main effects (all $p < 0.05$) across the 7-day period for distance completed within each speed category were also observed for each week (see Tables 2 and 3). To address issues with brevity, pairwise comparisons between specific days are reported in Tables 2 and 3 as well. We adopted the same method for data presentation as Anderson et al. (2016).

Table 2. Training and match duration (minutes) during the 7-day testing period for squad average.

	Day 1 MD+1	Day 2 MD-5	Day 3 MD-4	Day 4 MD-3	Day 5 MD-2	Day 6 MD-1	Day 7 MD
M1- 1-game week, n=10	X	X	36.5 ± 7.1 ^{b, c, d, e}	60.9 ± 3.3	88 ± 0	83 ± 0	87.1 ± 1.9
M2-1-game week, n=10	X	X	32.2 ± 20.9 ^{b, c, d, e}	65 ± 10.9	77 ± 0	76 ± 0	82.9 ± 21.0
	MD	MD+1	MD-4	MD-3	MD-2	MD-1	MD
M3-2-games week, n=8	79.3 ± 22.1	X	31.7 ± 25.9 ^{a, b, c, d}	81 ± 0	75 ± 0	75 ± 0	84.4 ± 8.1
	MD	MD+1	MD-3	MD-2	MD-1	MD	MD+1
M4- 2-games week, n=8	81.4 ± 20.7	65.1 ± 34.2	60.8 ± 11.4 ^c	71.3 ± 0.7 ^{c, d}	97.7 ± 0.9	86 ± 9.9	X
	MD	MD-2	MD-1	MD	MD-2	MD-1	MD
M5- 3-games week, n=8	73.1 ± 11.7	87 ± 0 ^a	90.2 ± 0.6	54.1 ± 11.0	74.4 ± 33.3	88 ± 0	56 ± 12.9

Bold indicates data obtained from matches. *a* denotes difference from day 3, *b* denotes difference from day 4, *c* denotes difference from day 5 and *d* denotes difference from day 6, *e* denotes difference from day 7, all $p < 0.05$.

Table 3. Distances covered at different speed thresholds (representative of squad average data) during training and matches completed in the 7-day testing period.

	Day						
	1	2	3	4	5	6	7
M1 - 1-game week	x	x	MD-4	MD-3	MD-2	MD-1	MD
Total Distance (m), n=10	x	x	6689.4±292.8 ^{b,d,e}	5388±1207.8 ^{c,d,e}	6708.5±483.2 ^{d,e}	2735.3±407.1 [*]	10011.4±1097.7
Zone1 (m), n=10	x	x	4559.8±118.5 ^{d,e}	3616.6±878.5 ^{c,e}	4802.5±183.0 ^{d,e}	2412.3±332.4 [*]	5987.1±537.5
Zone2 (m), n=10	x	x	1025.4±164.7 ^{d,e}	1007.2±292.6 ^{d,e}	836.5±139.0 ^{d,e}	185.8±57.6 [*]	1842.1±375.6
Zone3 (m), n=10	x	x	789.0±139.4 ^{d,e}	563.3±255.4 ^{d,e}	765.4±181.8 ^{d,e}	119.9±55.9 [*]	1387.5±349.4
Zone4 (m), n=10	x	x	243.4±28.4 ^{d,e}	162.6±98.3 ^{c,d,e}	255.1±66.4 ^{d,e}	16.6±16.9 [*]	572.6±162.2
Zone5 (m), n=10	x	x	87.4±0	31.2±35.5	24.9±6.1	2.7±2.9	265.0±161.2
RPE (AU), n=13	x	x	3.4±1.6	3.7±1.0 ^d	4.8±1.3 ^d	2.2±1.0	MD
s-RPE (AU), n=13	x	x	171.4±138.2 ^c	241.4±88.8 ^d	432.0±116.2 ^d	184.4±88.2	MD
M2-1-game week	x	x	MD-4	MD-3	MD-2	MD-1	MD
Total Distance (m), n=10	x	x	8409±190.1 ^{b,c,d}	6794.7±377.5 ^{c,d,e}	4023.9±559 ^{d,e}	2778.4±235.9 [*]	10089±2691.7
Zone1 (m), n=10	x	x	4856.3±2.6 ^{c,d}	4603.0±233.3 ^{c,d}	3006.9±360.2 ^{d,e}	2452.3±154.3 [*]	5642.7±1489.6
Zone2 (m), n=10	x	x	1341.9±161.4 ^{b,c,d,e}	1082.8±229.4 ^{c,d,e}	429.0±131.1 ^{d,e}	176.1±36.2 [*]	1936.1±567.9
Zone3 (m), n=10	x	x	820.1±35.1 ^{c,d,e}	789.8±148.2 ^{c,d,e}	423.0±99.3 ^{d,e}	117.8±60.3 [*]	1601.4±504.8
Zone4 (m), n=9	x	x	285.0±40.1 ^{c,d,e}	251.7±70.4 ^{c,d,e}	134.4±75.3 ^{d,e}	34.2±30.2 [*]	680.6±215.4
Zone5 (m), n=4	x	x	107.3±7.6	67.5±26.9	38.5±20.2	3.8±3.0	293.3±76.5
RPE (AU), n=13	x	x	3.7±2.2	5.4±1.9 ^d	3.9±1.5 ^d	2.2±0.8	MD
s-RPE (AU), n=13	x	x	227.2±202.8	412.4±156.7 ^d	301.0±115.3 ^d	168.9±60.3	MD
M3-2-game week	MD	x	MD-4	MD-3	MD-2	MD-1	MD
Total Distance, n=8	9509.4±2581.7^{b,c}	x	7232.0±73.9 ^{b,c,d}	6583.9±1016.3 ^{c,d}	5324.2±667.3 ^{d,e}	3991.6±615.9 [*]	9911.4±1883
Zone1 (m), n=8	5369.4±1498.4	x	4903.7±40.2 ^{c,d}	4506.3±400.8 ^d	3847.1±440.9 ^{d,e}	3192.6±291.5 [*]	5626.8±1215.4
Zone2 (m), n=8	1805.8±647.9^{a,b,c}	x	1105.6±80.8 ^{c,d,e}	979.9±354.7 ^{d,e}	640.0±210.9 ^{d,e}	405.8±186.4 [*]	2128.1±462.5
Zone3 (m), n=8	1378.3±526.8^{c,d}	x	733.2±31.2 ^{c,d}	779.6±315.1 ^{c,d}	536.6±70.9 ^{d,e}	288.8±138.3 [*]	1250.1±426.5
Zone4 (m), n=8	637.4±161.8^{a,b,c}	x	397.8±34.1 ^{b,c,d,e}	238.6±62.4 ^{d,e}	223.7±91.8 ^e	84.6±41.8 [*]	610.6±113.9
Zone5 (m), n=5	323.4±143.9	x	48.3±0	72.0±27.6	89.8±69.2	31.8±14.0	248.8±92.2
RPE (AU), n=13	MD	x	3.5±1.6	4.8±1.2 ^d	4.3±1.2 ^d	2.5±1.4	MD
s-RPE (AU), n=13	MD	x	208.3±170.7 ^b	388.3±98.1 ^d	320.5±87.1 ^d	187.5±108.3	MD
M4- 2-game week	MD	MD-4	MD-3	MD-2	MD-1	MD	x
Total Distance (m), n=7	9815.9±3072.3^{a,c}	7531.7±8.0 ^{a,c,d}	4862.9±827.2 ^d	6181.5±850.7 ^d	3911.6±545.8 ^d	10355.4±859.7	x
Zone1 (m), n=8	5225.9±2638.2	5646.1±19.4 ^{a,b,c}	3711.2±201.6 ^d	4514.7±188.6 ^{c,d}	2910.7±67.1 ^d	6364.8±237.3	x
Zone2 (m), n=8	1584.0±773.3	892.7±46.5 ^d	871.4±309.7 ^d	876.5±226.8 ^d	527.0±383.7 ^d	1821.8±174.3	x
Zone3 (m), n=8	1242.4±552.4^c	627.8±26.7 ^{a,c,d}	299.7±145.9 ^{b,d}	710.1±159.4 ^{c,d}	343.9±69.8 ^d	1495.6±320.9	x
Zone4 (m), n=7	435.1±193.4^{a,c}	329.1±34.0 ^{a,b,c}	50.1±29.8 ^{b,c}	150.9±43.0 ^d	95.1±48.9 ^d	498.6±174.7	x
Zone5 (m), n=5	136.8±71.2	90.2±52.1	14.2±15.6	25.4±15.0	36.5±17.0	126.8±51.3	x
RPE (AU), n=13	MD	2.9±1.3 ^b	2.8±1.1 ^b	4.5±1.3	2.9±0.8	MD	x
s-RPE (AU), n=13	MD	198.9±131.1	167.6±79.8 ^{b,c}	330.3±123.1	273.4±66.8	MD	x
M5- 3-game week	MD	MD-2	MD-1	MD	MD-2	MD-1	MD
Total Distance (m), n=8	8805.9±4040.4	5855.6±246.5 ^{a,d}	4427.6±318.5 ^{c,d}	6657.5±3776.7	6691.9±690.4 ^d	3619.8±356.8	7444.1±4639.6
Zone1 (m), n=8	4979.8±2328.7	4361.2±220.6 ^{a,d}	3469.8±187.9 ^{c,d}	3666.0±2343.7	4519.7±442.0 ^d	2994.8±199.7	3789.5±2408.2
Zone2 (m), n=8	1751.9±776.3^{a,d}	642.5±116.9 ^{a,d}	446.3±96.2 ^{c,d}	1304.1±749.3	941.9±263.9 ^d	289.6±85.9	1507.1±930.2
Zone3 (m), n=8	1312.1±741.1	616.5±145.3 ^{c,d}	404.3±152.6 ^c	1071.8±560.7^d	900.5±177.4 ^d	255.4±98.4	1348.5±963.7
Zone4 (m), n=8	555.4±311.2	206.8±57.1 ^{a,d}	98.3±45.2	464.8±231.9^d	280.6±120.2 ^d	70.1±32.8	573.8±364.6
Zone5 (m), n=6	250.5±145.6	33.4±19.9	6.8±3.6	164.5±104.0	49.9±31.8	12.8±9.2	203.0±189.5
RPE (AU), n=13	MD	3.6±0.3 ^{a,d}	2.6±0.3 ^c	MD	3.6±0.3 ^d	2.8±0.3	MD
s-RPE (AU), n=13	MD	316.4±95.8	241.0±90.7	MD	272.7±70.9	246.4±78.7	MD

MD= matchday MD (-) = matchday minus (4, 3, 2, 1); AU= arbitrary units; m= meters; RPE= rating of perceived effort exertion; s-RPE= session rating of perceived exertion; X= Day Off. Bold indicates data obtained from matches. a denotes difference from day 3, b denotes difference from day 4, c denotes difference from day 5, d denotes difference from day 6 and e denotes difference from day 7, all p < 0.05.

One-game week schedule, M1

During training sessions, total distance covered in day 3 > day 4 (1031.4 m, ES = 1.48), < day 5 (-19.1 m, ES = 0.05), > 6 (3954.1 m, ES = 11.15). Also, day 4 < day 5 (-1320.5 m, ES = 1.44), > day 6 (2652.7 m, ES = 2.94). Day 5 > day 6 (3973 m, ES = 8.89).

For zone 1, the significant results point to day 3 > 6 (2147.5 m, ES = 6.86). Also, day 4 < day 5 (-1185.9 m, ES = 1.87). Day 5 > day 6 (2390.2 m, ES = 8.91).

For zone 2, the significant results point to day 3 > 6 (839.6 m, ES = 6.81). Also, day 4 > day 6 (+714.6 m, ES = 3.90). Day 5 > day 6 (677.7 m, ES = 6.12).

For zone 3, the significant results point to day 3 > 6 (669.1 m, ES = 6.30). Also, day 4 > day 6 (-202.1 m, ES = 0.91). Day 5 > day 6 (-645.5 m, ES = 4.80).

For zone 4, the significant results point to day 3 > 6 (226.8 m, ES = 9.71). Also, day 4 < day 5 (-92.5 m, ES = 1.10), > day 6 (+146 m, ES = 2.07). Day 5 > day 6 (238.5 m, ES = 4.92).

For RPE, the significant results point to day 4 > day 6 (0.5 arbitrary units (au), ES = 1.50) and day 5 > day 6 (2.6 au, ES = 2.40).

For s-RPE, the significant results point to day 3 < day 5 (-260 au, ES = 2.04); day 4 < day 5 (-190.6 au, ES = 1.84); day 5 > day 6 (247.6 m, ES = 2.40).

One-game week schedule, M2

During training sessions, total distance covered in day 3 > day 4 (1614.3 m, ES = 5.40), > day 5 (4385.1 m, ES = 10.50), > 6 (5630.6 m, ES = 26.28). Also, day 4 > day 5 (2770.8 m, ES = 5.81), > day 6 (4016.3 m, ES = 12.76). Day 5 > day 6 (1245.5 m, ES = 2.90).

For zone 1, the significant results point to day 3 > day 5 (1849.4 m, ES = 7.26), > day 6 (2404 m, ES = 22.03). Also, day 4 > day 5 (1596.1 m, ES = 5.26) and > day 6 (2150.7 m, ES = 10.87). Day 5 > day 6 (+554.6 m, ES = 2.00).

For zone 2, the significant results point to day 3 > day 4 (259.1 m, ES = 1.31), > day 5 (912.9 m, ES = 6.21), > 6 (1165.8 m, ES = 9.97). Also, day 4 > day 5 (653.8 m, ES = 3.50), > day 6 (906.7 m, ES = 5.52). Day 5 > day 6 (252.9 m, ES = 2.63).

For zone 3, the significant results point to day 3 > day 5 (397.1 m, ES = 5.33), > 6 (702.3 m, ES = 14.24). Also, day 4 > day 5 (366.8 m, ES = 2.91), > day 6 (672 m, ES = 5.94). Day 5 > day 6 (305.2 m, ES = 3.72).

For zone 4, the significant results point to day 3 > day 5 (150.6 m, ES = 2.50), > 6 (250.8 m, ES = 7.07). Also, day 4 > day 5 (117.3 m, ES = 1.61), > day 6 (217.5 m, ES = 4.02). Day 5 > day 6 (100.2 m, ES = 1.75).

For RPE, the significant results point to day 4 > day 6 (3.2 au, ES = 2.20) and day 5 > day 6 (1.7 au, ES = 1.41).

For s-RPE, the significant results point to day 4 > day 5 (111.4 au, ES = 0.81); day 5 > day 6 (132.1 au, ES = 1.44).

Two-game week schedule, M3

During training sessions, total distance covered in day 3 > day 4 (648.1 m, ES = 0.90), > day 5 (1907.8 m, ES = 4.02), > 6 (3240.4 m, ES = 7.39). Also, day 4 > day 5 (1259.7 m, ES = 1.47), > day 6 (2592.3 m, ES = 3.08). Day 5 > day 6 (1332.6 m, ES = 2.08).

For zone 1, the significant results point to day 3 > day 5 (1056.6 m, ES = 3.38), > day 6 (1711.1 m, ES = 8.22). Also, day 4 > day 6 (1313.7 m, ES = 3.75). Day 5 > day 6 (654.5 m, ES = 1.75).

For zone 2, the significant results point to day 3 > day 5 (465.6 m, ES = 2.92), > 6 (699.8 m, ES = 4.87). Also, day 4 > day 6 (571.1 m, ES = 2.03). Day 5 > day 6 (234.2 m, ES = 1.18).

For zone 3, the significant results point to day 3 > day 5 (196.6 m, ES = 3.59), > 6 (444.4 m, ES = 4.43). Also, day 4 > day 5 (243 m, ES = 1.06), > day 6 (490.8 m, ES = 2.02). Day 5 > day 6 (247.8 m, ES = 2.25).

For zone 4, the significant results point to day 3 > day 4 (159.2 m, ES = 3.17), > day 5 (174.1 m, ES = 2.51), > 6 (313.2 m, ES = 8.21). Also, day 4 > day 6 (154 m, ES = 2.90). Day 5 > day 6 (139.1 m, ES = 1.95).

For RPE, the significant results point to day 4 > day 6 (2.3 au, ES = 1.76) and day 5 > day 6 (1.8 au, ES = 1.38).

For s-RPE, the significant results point to day 3 < day 4 (-180 au, ES = 1.29); day 4 > day 6 (200.8 au, ES = 1.94); day 5 > day 6 (133 au, ES = 1.35).

Two-game week schedule, M4

During training sessions, total distance covered in day 2 > day 3 (2668.8 m, ES = 4.56), > day 5 (3620.1 m, ES = 9.38).

For zone 1, the significant results point to day 2 > day 3 (1934.9 m, ES = 13.51), > day 4 (1131.4 m, ES = 8.44), > day 5 (2735.4 m, ES = 55.38). Also, day 4 > day 5 (1604 m, ES = 11.33).

For zone 3, the significant results point to day 2 > day 3 (328.1 m, ES = 3.13), > day 5 (283.9 m, ES = 5.37). Also, day 3 > day 4 (-410.4 m, ES = 2.69). Day 4 > day 5 (366.2 m, ES = 2.98).

For zone 4, the significant results point to day 2 > day 3 (279 m, ES = 8.73), > day 4 (-82.3 m, ES = 0.72), > day 5 (234 m, ES = 5.56). Also, day 3 > day 4 (-100.8 m, ES = 2.72), > day 5 (-44.2 m, ES = 0.39).

For RPE, the significant results point to day 2 < day 4 (-1.6 au, ES = 1.23) and day 3 < day 4 (-1.7 au, ES = 1.41).

For s-RPE, the significant results point to day 3 < day 4 (-167.7 au ES = 1.57) and day 5 (-105.8 au, ES = 1.44).

Three-game week schedule, M5

During training sessions, total distance covered in day 2 > day 3 (1428 m, ES = 5.01), > day 6 (2235.8 m, ES = 7.29). Also, day 3 > day 5 (-2264.3 m, ES = 4.21) and > day 6 (807.8 m, ES = 2.39). Finally, day 5 > day 6 (3072.1 m, ES = 5.59).

For zone 1, the significant results point to day 2 > day 3 (891.4 m, ES = 4.35), > day 6 (2235.8 m, ES = 7.29). Also, day 3 > day 5 (-1049.9 m, ES = 3.09) and > day 6 (475 m, ES = 2.45). Finally, day 5 > day 6 (1524.9 m, ES = 4.45).

For zone 3, the significant results point to day 2 < day 5 (-284 m, ES = 1.75), > day 6 (361.1 m, ES = 2.91). Also, day 3 > day 5 (-496.2 m, ES = 3.00). Finally, day 5 > day 6 (816.4 m, ES = 2.03).

For zone 4, the significant results point to day 2 > day 3 (108.5 m, ES = 2.11), > day 6 (136.7 m, ES = 2.94). Also, day 5 > day 6 (210.5 m, ES = 2.39).

For RPE, the significant results point to day 2 > day 3 (1 au, ES = 3.33), > day 6 (0.8 au, ES = 2.67). Also, day 3 < day 5 (-0.8 au, ES = 2.67). Finally, day 5 > day 6 (0.8 au, ES = 2.67).

Comparisons between microcycles

Duration and distance covered for training sessions and matches were rated according to a perceived exertion scale; s-RPE and CK values from the training sessions were compared for all microcycles. There are no differences for total distance, training intensity of zones 2, 4, and 5, s-RPE and RPE, $p < 0.05$.

However, there were significant differences between several of the microcycles for some variables. For example, there is significant difference in training intensity of zone 1 between M2 and M4 (4010.2 ± 103.5 vs 4507.6 ± 133.0 m, respectively, ES = 4.17 (2.70, 5.38)).

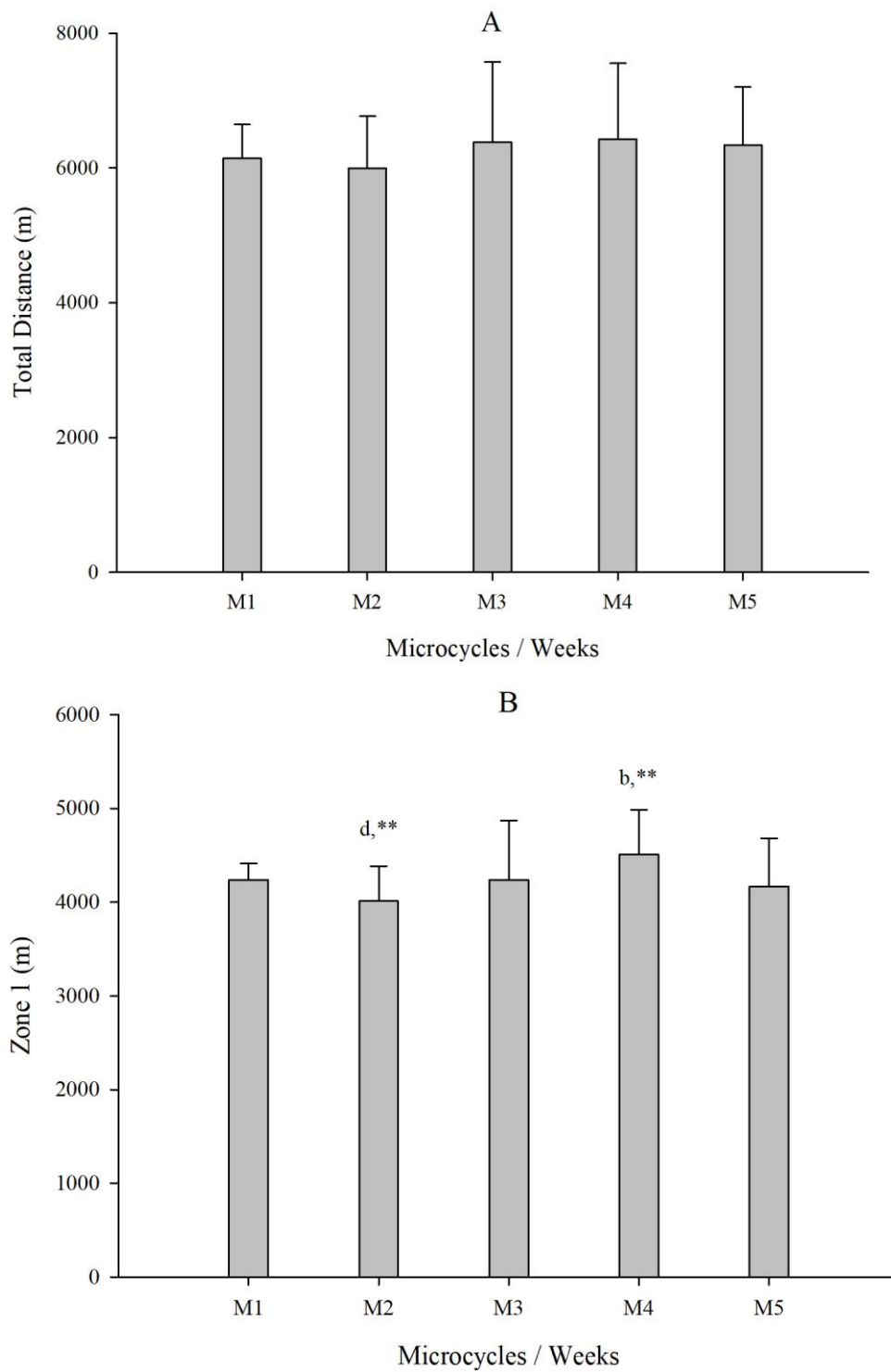


Figure 1. Comparisons between 5 microcycles/weeks for total distance and training intensity of zone 1 (0-10.9km/h). a denotes difference from M1, b denotes difference from M2, c denotes difference from M3, d denotes difference from M4 and e denotes difference from M5, all $p < 0.05$. * moderate effect size, ** very large effect size.

There was a significant difference in training intensity of zone 3 and 4 between M1 and M5 ((686.1 \pm 42.8 vs 801.2 \pm 61.2 m, respectively, ES = 2.18 (1.15, 3.07) and 241.6 \pm 48,6 vs 302.8 \pm 76,14, ES = 0.98 (1.92, 0.04))-as well as a difference in duration of training sessions and matches between M2 and M5 (69.2 \pm 2.1 vs 79.6 \pm 2.3, respectively, ES = 4.72 (3.11, 6.03) and M3 and M5 (69.7 \pm 1.0 vs 79.6 \pm 2.3, respectively, ES = 5.58 (3.75, 7.06)).

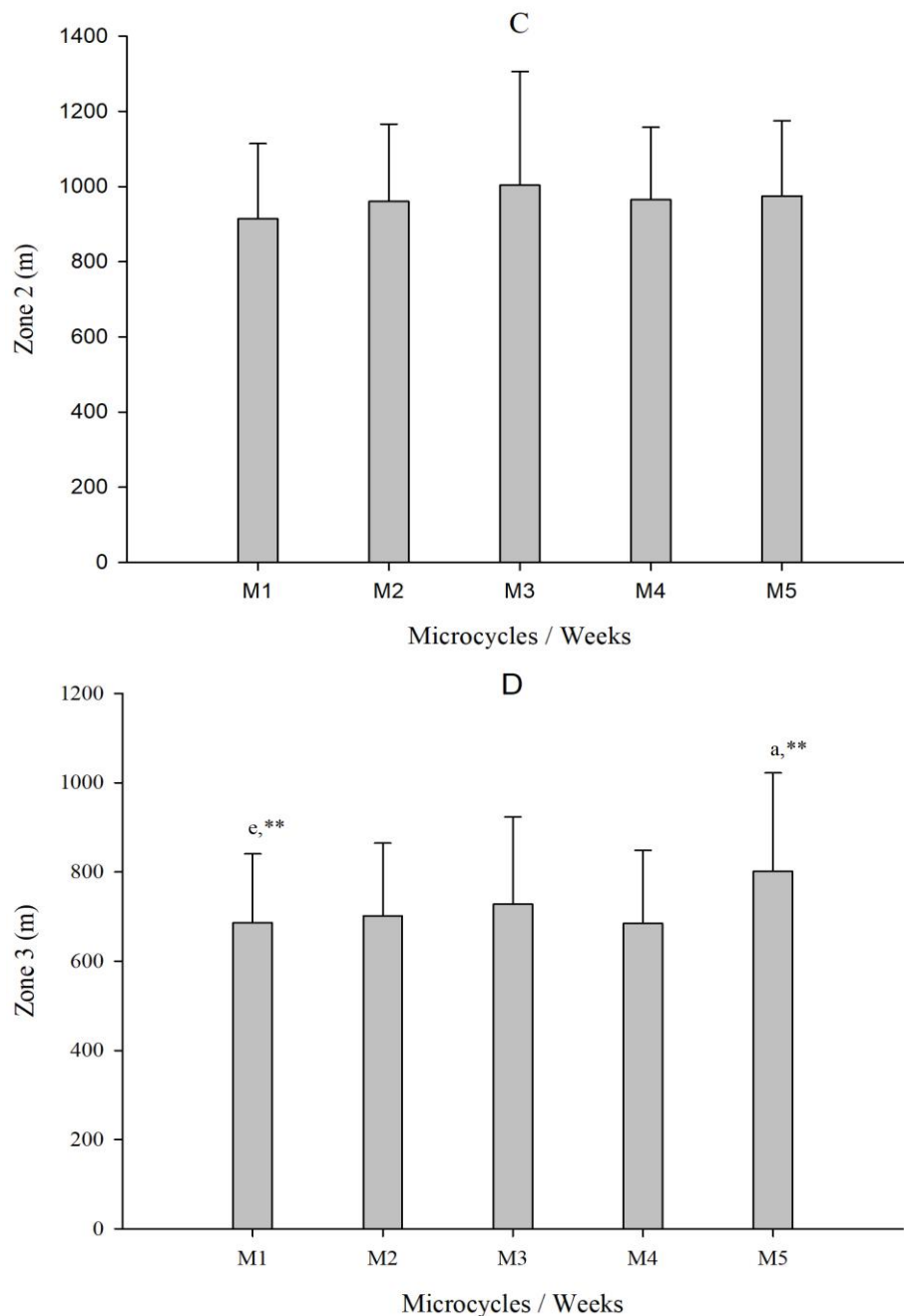


Figure 2. Comparisons between 5 microcycles/weeks for training intensity of zones 2 (11-13.9 km/h) and zone 3 (14-18.9 km/h). a denotes difference from M1, b denotes difference from M2, c denotes difference from M3, d denotes difference from M4 and e denotes difference from M5, all $p < 0.05$. * moderate effect size, ** very large effect size.

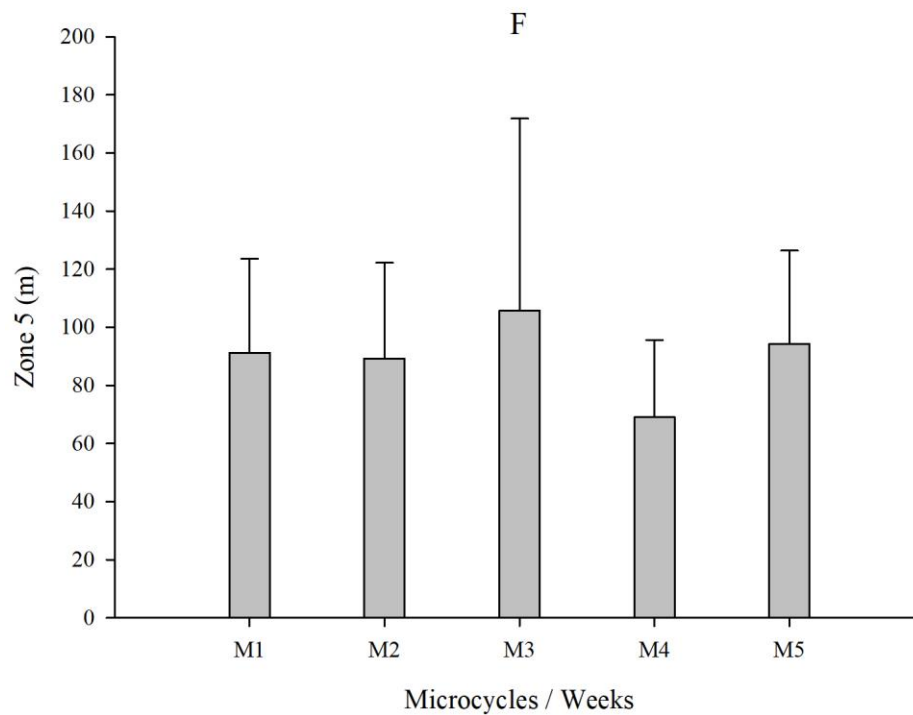
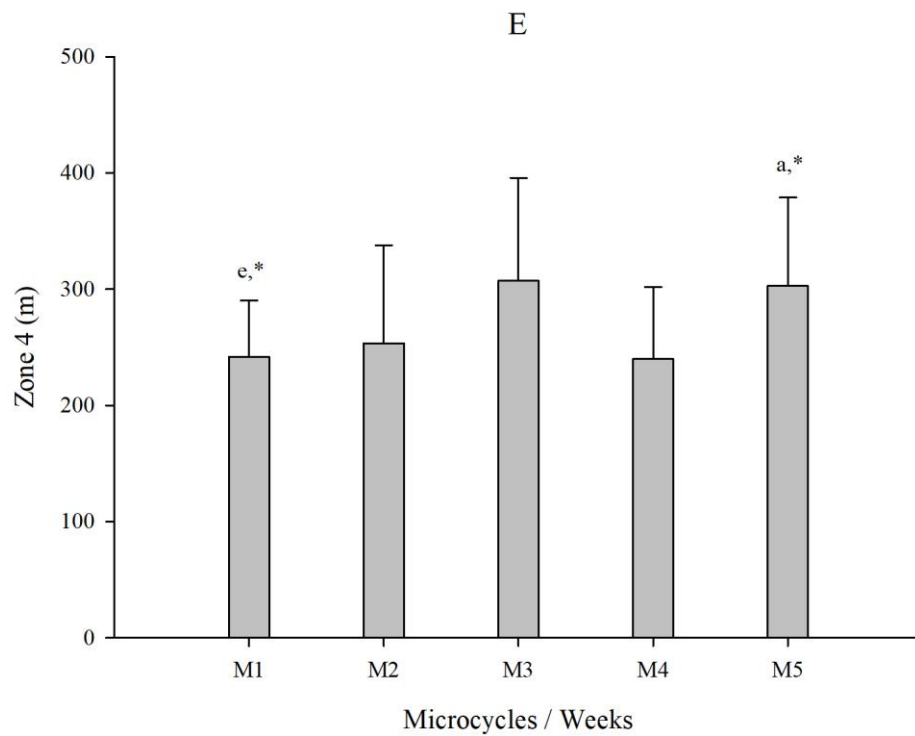


Figure 3. Comparisons between 5 microcycles/weeks for training intensity of zone 4 (19-2.9 km/h) and zone 5 (> 24km/h). a denotes difference from M1, b denotes difference from M2, c denotes difference from M3, d denotes difference from M4 and e denotes difference from M5, all $p < 0.05$. * moderate effect size, ** very large effect size.

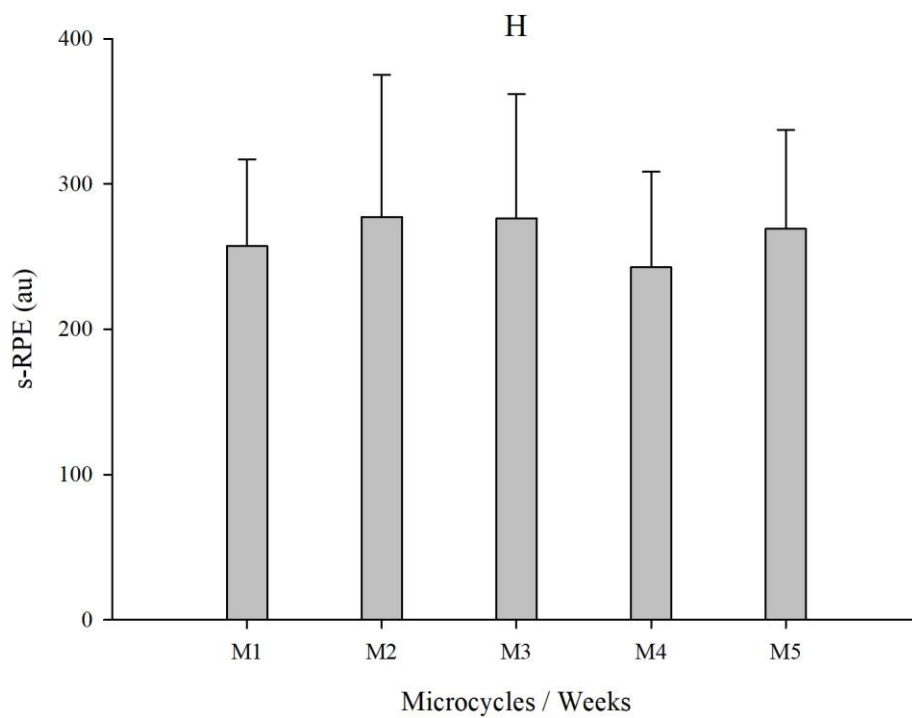
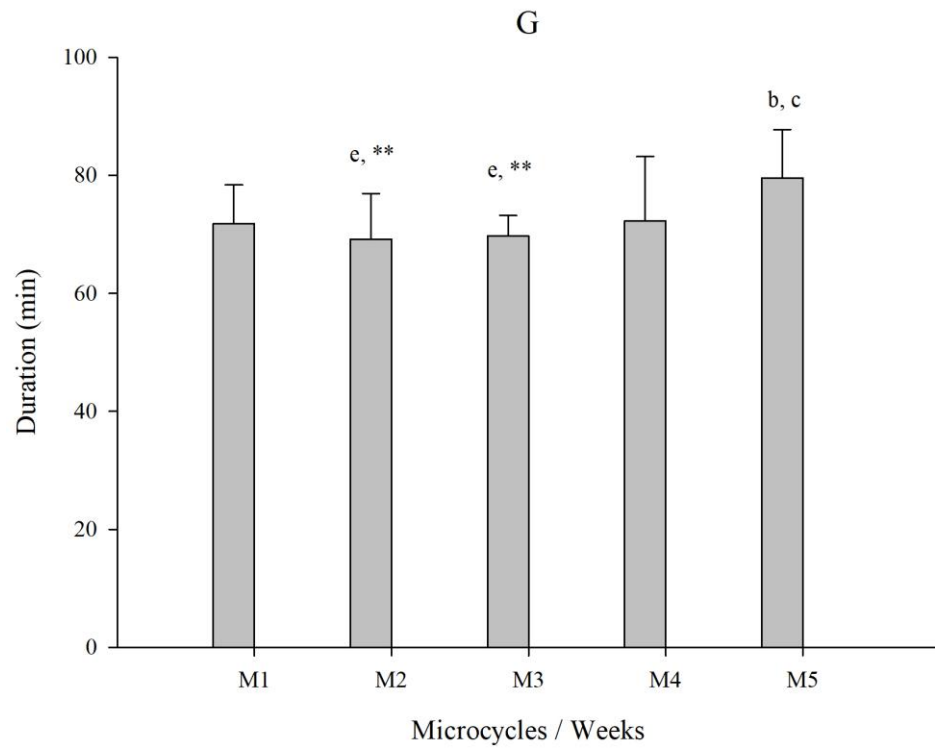


Figure 4. Comparisons between 5 microcycles/weeks for duration and s-RPE. a denotes difference from M1, b denotes difference from M2, c denotes difference from M3, d denotes difference from M4 and e denotes difference from M5, all $p < 0.05$. * moderate effect size, ** very large effect size.

Finally, there was significant difference in CK between M3 and M2 (325.5 ± 155.0 vs 194.4 ± 48.9 , respectively, $ES = 1.14$ (0.28, 1.93)).

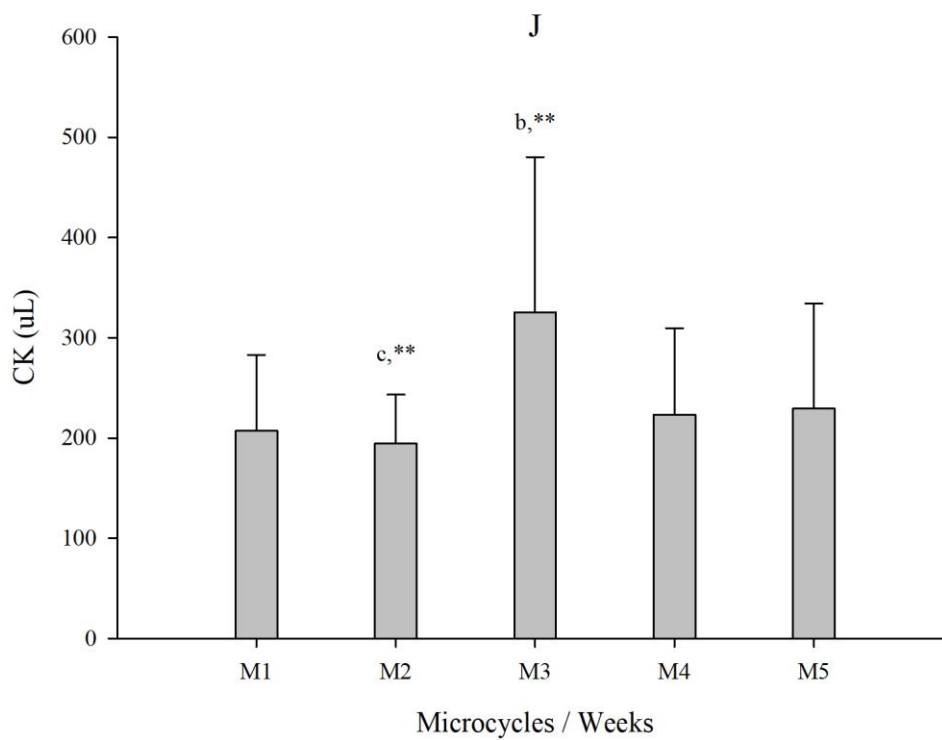
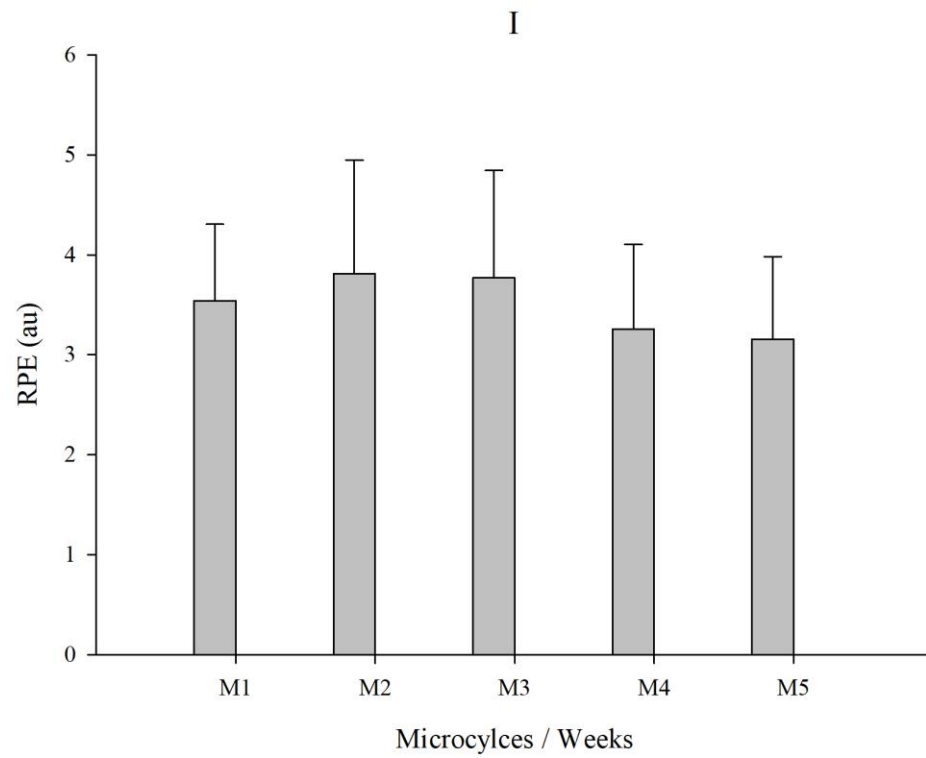


Figure 5. Comparisons between 5 microcycles/weeks for RPE and CK. a denotes difference from M1, b denotes difference from M2, c denotes difference from M3, d denotes difference from M4 and e denotes difference from M5, all $p < 0.05$. * moderate effect size, ** very large effect size.

Discussion

The main aim of this study was to determine the TLs of weekly microcycles, in which a different number of matches occur, for a professional male elite soccer team. To the best of our knowledge, this study provides the first report of daily external and internal TL and weekly accumulated load (training sessions and match demands) for one, two, and three-game week schedules in a sample of elite soccer players. This study found significant differences in daily and accumulated loads for the within- and between-game schedules.

Comparison between days of the week-pattern microcycles

In general, the TL is different between training sessions depending on the number of games (one, two, or three) per week.

The internal TL analyzed through s-RPE does not seem to have a pattern in the different microcycles. These results contradict previous studies (Anderson et al., 2016; Jeong et al., 2011; Owen et al., 2016a), which have found an intense s-RPE pattern exists in the beginning of the different microcycles.

The s-RPE is a viable method to characterize training responses in players (Coutts, Rampinini, Marcora, Castagna & Impellizzeri, 2009; Foster et al., 1995, 2001; Foster, 1998), however, our results indicate that s-RPE does not follow the same pattern as the external TL variables. Indeed, several studies have stated that RPE may be a physiological and volatile construct that could differ depending on the cognitive focus of a given player (Baden, McLean & Tucker, 2005; Ferraz et al., 2018, 2017; Gibson, Lambert, Rauch & Tucker, 2006). Also, Renfree, Martin, Micklewright and Gibson (2014) have reported that RPE can be dissociated from the physiological process through a variety of psychological mechanisms, such as, many positive/negative game training experiences, confrontations with team-mates/coaches or even some life issues that can interfere in positive/negative way to the given RPE. For this reason, RPE may be an oversimplification of the psychophysiological perceived exertion and a non-conclusive measure to capture a wide range of experienced sensations (Halson, 2014; Impellizzeri et al., 2006; Taylor, 2012). It is also important to note that RPE was collected 30 min after the end of each training session and it would be pertinent to check whether there are any atypical variations during the training sessions, as stated by Ferraz et al. (2017). These arguments may explain why there were no differences in s-RPE between training days, as well as why there appears to be a lack of relationship between s-RPE and the external TL variables.

When s-RPE was analyzed in the 1-game week microcycle, there was no significant difference in s-RPE for days 4 and 5 (MD-3 and MD-2, respectively), although there was a slight difference when compared to day 6 (MD-1). Thus, it is likely that days 4 and 5 (MD-3 and MD-2, respectively) were higher loading days, while day 6 (MD-1) was a tapering session for the match.

There were no differences in s-RPE between days 3 and 6 (MD-4 and MD-3, respectively), being the first one of recovery and the other of tapering. The load distribution found in this study is similar to that reported in several other studies (Anderson et al., 2016; Malone et al., 2015; Stevens et al., 2017).

With regard to the 2-game week microcycle (M3 and M4), there were no differences in s-RPE for days 4 and 5 (respectively, MD-3 and MD-2). Days that exhibited higher TL (MD-4) appear to be merely coincidental in our study, although Anderson et al. (2016) have reported that MD-3 regularly exhibits higher TL than other days. In the study conducted by Anderson et al. (2016), one day-off was given after each match-day, which likely meant that MD-4 was a recovery training session and would therefore, exhibit lower TL.

Singularly, for M5 (for the 3-game week microcycle), the day after the match exhibited greater s-RPE (MD-2, corresponding to days 2 and 5 of the week) but no significant difference was found. Only considering RPE, however, there was a significant difference between MD-2 and MD-1 (corresponding to day 2 and day 3; and day 5 and day 6, respectively). This 3-game week microcycle did not have a single day-off, unlike in the study conducted by Anderson et al. (2016), occurring 2 training sessions between matches.

As match-day approaches, external TL (as total distance and distances covered at different running speed thresholds during training) decreases in almost all week-pattern microcycles. Moreover, our results indicate that external TL is highest at the beginning of the microcycle: this is likely done to ensure that fatigue is minimal as match-day nears. Several studies have stressed the importance of varying daily TLs (i.e. alternation of low- and heavy-load training days) to achieve optimal performance on match-day (Anderson et al., 2016; Malone et al., 2015; Scott et al., 2013). Stevens et al. (2017) have reported the highest external TL on the first training-day of the week. Akenhead et al. (2016) have found that, for an entire season, the highest external TL typically occurs on the second training-day of the 1-game week. Also, Anderson et al. (2016) have reported highest external TL on the second for 1- and 2-game week. The findings of Malone et al. (2015) indicate no differences in external TL between the first three training-days of the week, but their study analyzed a 6-week pattern of 1-game week. Several studies involving English Premier League teams have also found that during a typical week-pattern microcycle - 6 full days between matches - the last training-day before the match (MD-1) commonly has the lowest load (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015). These results indicate that differences exist in the distribution of TL between high-level football teams, especially in the first three training-days of the microcycle of a full training week-pattern microcycle. The present study found that the first day of a week's training sessions exhibits higher TL values, which decrease until MD-1, independent of the number of games per week.

In one-game week microcycles, the training-days with higher TLs were not coincident. In M1, the MD-2 exhibited greater total distance and high-speed running zones (> 19 km/h), whereas in M2, the MD-4 exhibited higher TL. The load distribution pattern of M2 after the first training session of the week for a 1-game week is similar to those reported within the literature (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015; Stevens et al., 2017). Possible reasons for these differences could be the association between the different training session durations (table 2) and the different levels of intensity applied by the coach. For example, M1 in MD-2 exhibited a longer duration (88 min) and therefore, higher values. However, M2 had higher values in MD-4 with a duration of only 32 min. This can possibly be explained by the application of a high-intensity training approach or simply due to the context and competitive schedule and the objectives related to the TL management.

With regard to the 2-game week microcycle (M3), all external TL variables decreased from MD-4 to MD-1, and there was a significant difference of MD-1 for all days. However, M4 exhibited a different pattern: MD-4 $>$ MD-3 $<$ MD-2 $>$ MD-1, which means that MD-4 and MD-2 exhibited higher TL. Anderson et al. (2016), when examining the same week pattern, reported that MD-3 exhibits the highest TL. However, it is important to note that in their study, there was a day-off after the match-day, which likely means that MD-4 was used for a recovery training session and therefore, would exhibit a lower TL.

Singularly, in the M5 (3-game week microcycle), the day with the greater external TL was the day after the match (MD-2, corresponding to days 2 and 5 of the week) for total distance and all covered distances (zones 1, 2, 3, 4 and 5) and there were significant differences between MD-2 and MD-1 (corresponding to day 2 and day 3, and day 5 and day 6) with the exception of zone 5, high-speed running distance (> 25 km/h), which did not exhibit any significant differences. Moreover, this 3-game week microcycle did not have a day-off, unlike in the study conducted by Anderson et al. (2016), occurring 2 training sessions between matches. Similarly, high-speed running zone 5 (> 25 km/h) decreased as match-day approached, however no differences were observed between all training days within each week-pattern microcycle (table 3). Moreover, no pattern was determined for these days, except for the day before the match.

Comparison between microcycles

In the present study, there were no significant differences between internal TL, s-RPE and RPE for microcycles of one-, two- or three-game weeks (see Figures 1-5). In contrast, Clemente et al. (2017) found significant differences in s-RPE between microcycles of one- and two-game weeks and found smaller values of s-RPE in two-game weeks compared to one-game week. The results suggest that s-RPE may be sensitive to congested periods, but not sensitive to regular periods of training during one-game week (Clemente et al., 2017). Furthermore, as reported

above, RPE may be a psychophysiological and volatile construct (Ferraz et al., 2017; 2018; Gibson et al., 2016; Renfree et al., 2014).

A comparison of the weekly internal load for the 3-game week microcycles found that, despite a different distribution of loads across the training microcycle (7 days), the overall TL remains constant (i.e. training sessions plus games loads). Moreover, despite the number of games played in a week, there is no significant difference between weekly s-RPE imposed during actual week-pattern microcycles (1-, 2-, and 3-game weeks, respectively).

Considering the accumulated weekly TL, it is possible to obtain more detailed information regarding the actual subjective response to training prescription for coaches (Impellizzeri et al., 2004, 2006). In the present study, there is no difference between microcycle for s-RPE and their mean range weekly TL was 243-277 au. The weekly s-RPEs collected by this study are in accordance with what has previously been found by Scott et al. (2013), in the range of 38-936 au, but higher than 187 au for elite soccer players (Jeong et al., 2011). Unlike in our study, Jeong et al. (2011) only used elite professional Korean soccer players while the present study comprises top European soccer players who compete in UEFA competitions. Moreover, the mean for the total weekly TL (based on s-RPE) corresponds to a range of 970-1110 au, as a reference for training session prescriptions.

With regard to concentrations of plasma CK, it appears that coaches use this approach to determine whether athletes are ready to compete in upcoming matches (Halsen, 2014). They use this measurement to prevent injury, observe the effectiveness of an implemented training program, maintain athlete performance and prevent overtraining (Taylor, 2012). In fact, several studies have reported significant correlations between CK and running speeds > 4 m/s, accelerations and decelerations over a certain magnitude (moderate to high). It has even been suggested that a certain volume of movement at these speeds is necessary for the movement to be strongly associated with CK levels (Young, Hepner & Robbins, 2012). However, the data collected only reveal a significant difference between M3 and M2 (325.5 ± 155.0 and 194.4 ± 48.9 , respectively), as can be observed in figure 5. M3 has higher values of CK, which may be associated with high-intensity training sessions, accumulated TL or incomplete recovery of players 48 hours before a given match. High CK levels could reveal high variability and a not consistent relationship with muscle recovery exists which possibly means that CK could be an inconsistent marker, with large intra and interindividual variability when used alone, as suggested in previous study (Twist & Highton, 2013). Finally, CK was only collected 48 h prior to the matches. For future research it is required to collect data from training sessions and matches to better understanding of the results.

For external TL with 1-, 2- and 3-game weeks, the average data obtained are as follows: training duration (67.4; 70.5 and 85.5 min, respectively), total distance (5340.5; 5668.7 and 5105.5 m, respectively), running (195.1; 148.4 and 175.6 m, respectively) and high-speed running (58.5;

46.1 and 22.6 m, respectively). All obtained data are in similar ranges to what other studies have demonstrated (65-77 min, 3898-5667 m, 220-591 m and 41-205 m, respectively) (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015; Scott et al., 2013; Stevens et al., 2017).

We also found no significant differences between microcycles for total distance and for high-speed running distance for zone 5 (> 25 km/h). The only difference found concerned the training intensity of zone 4 between M1 and M5. One plausible reason for this may be that there was no change in TL during the microcycles studied, and possibly during all microcycles for the entire in-season. Indeed, coaches and fitness trainers may have imposed a similar weekly TL throughout the entire competitive season, despite the number of games, in the attempt not to overload players.

Anderson et al. (2016) have found that, with regard to 2-game weeks, the total weekly accumulated distance and duration of activity is higher than in the 1-game week schedule and includes significantly more time spent in high-intensity zones. However, our results are in accordance with several other studies (Dellal, Lagos-Peñas, Rey, Chamari & Orhant, 2015), which have reported no differences between total distance and intensity training zones for 1- and 2-game week microcycles. Once again, these differences may be associated with differences in training session duration (table 2) and intensity, neither of which were controlled for this study.

Anderson et al. (2016) have also stated that the total duration of training sessions and games was higher in the 2-game weeks than in the 1- and 3-game week microcycles. These results contradict the findings in this study, which indicate a higher total duration in the 3-game week microcycles. However, it is important to note that the results of the training sessions during the microcycles studied by Anderson et al. (2016) were different from our study. For instance, in a 3-game week microcycle, there were only two training sessions, while in our study there were four.

Moreover, Anderson et al. (2016) determined a higher total distance covered in the 3-game week compared with the 1-game week. In our study, however, we did not find any significant difference likely due to the distances covered during matches. The study of Anderson et al. (2016) revealed that the coach adjusts the load for different week-pattern microcycles. Indeed, the coach increased the total distance covered in a 1-game week training session, then decreased it in a 2-game week, and then further decreased it during a 3-game week.

In accordance with the findings of Owen et al. (2016a), it is expected to reduce TL two days before a match to reduce the number of physical stressors imposed upon the players. This statement agrees with our results if we consider the values of all internal and external TL for the last day of all the microcycles studied. As reported by Stevens et al. (2017), in different full-week microcycles there is limited time for recovery and physiological conditioning, since

the last days were too close to the match and therefore would most probable cause pre-match fatigue. Our TL data conforms to this statement (table 3).

Although several studies determined that training sessions differed depending on how many games were played each week (one, two, or three), our study reveals that, during in-season for a top European soccer team, matches are probably the most important physiological stimulus during the competitive season.

The simultaneous use of both GPS and tracking system to quantify training sessions and matches, respectively, has obvious implications for the comparability of data between systems (Anderson et al., 2016; Issurin, 2010).

This study is also reflective of one top elite European soccer team only that played European matches and may not be representative of the customary training demands of other domestic teams that did not played European matches (Gaudino et al., 2013) that may be influenced by different coaching philosophies (Anderson et al., 2016). Although the weekly scenarios were based on the number of players who completed all training sessions and played at least one match in each microcycle, it is possible that the results may be different if we include players that also completed exercise training sessions, but zero matches. This could be considered for future research. Also, all microcycles analysed were related to home matches what could interfere in the results.

Conclusions

To the best of our knowledge, this is the first study to report a specific analysis of 1-, 2-, and 3-game weeks of internal and external TL simultaneously. Indeed, this study quantifies the daily training and accumulative weekly and match load in professional elite European soccer team during a one-, two- and three-game week schedule. It is important to note that customary TLs did not exhibit a regular pattern for one- and two-game week microcycles for either external TL (distances of different exercise training intensity zones) nor internal TL (s-RPE, CK). Moreover, the evidence indicates a particular fact of periodisation in training during the day before a match, because all external and internal TL variables were reduced. Another major finding is that the values of external TL for distances of different exercise training intensity (zones 2-5) were never reached in training sessions in comparison to the values resported in matches. The enzymatic parameter CK did not increase in weeks with two- or three-game weeks as expected, which confirms that weekly match load was likely considered in the daily management of TL (during training sessions).

Our study also reveals that internal training and external training differ on a daily basis during different microcycles. Moreover, in each analysis performed, there may be no correspondence between them. As such, a careful analysis of each variable should be conducted for each day or each microcycle. Future studies should also consider, for example, an individualized analysis of the TL (external and internal) in accordance with the position of the players. Furthermore, is important to understand whether several contextual variables, such as the opponent level, the match result or the time during the season, could affect the results.

Practical Applications

This study provides useful information regarding the TLs of an elite European soccer team that plays in a European Champions league. It provides further evidence of the value of using a combination of different monitoring measures to fully evaluate the TL patterns observed across a full competitive season. Moreover, appropriate doses of training stimulus could improve performance and protect against possible injury (Marqués-Jiménez et al., 2017). It is, therefore, important for physical fitness and sports technicians to determine the optimum quantity of training required for a player to continue improving his/her physical fitness, while reducing the probability of injury, in order to maximize his/her performance during competition.

For coaches, this study could provide important information to be considered when planning training sessions. The significant differences found in daily and accumulated loads within- and between-game schedules could have implications for weekly periodization. To ensure that fatigue is properly managed, TLs should be adjusted at various times during the different week microcycles.

Based on the data obtained, it is possible to retrospectively examine load-performance relationships and to enable appropriate planning for TLs depending on the number of games. Data may also be useful for team selection and determining which athletes are ready for the demands of competition.

Data collected from the training monitoring can also be useful to facilitate communication between the support staff and the coaching staff.

Chapter 4. General Discussion

The aim of this thesis was to quantify the external and internal training load (TL) of elite soccer athletes during an in-season. Studies 1 and 2 attempted to quantify TL in one-, two- and three-game weeks and throughout the entire in-season based on ten mesocycles (months) using the match-day minus/plus approach. The results indicated a significant decrease in external TL in the last day prior to a match for all microcycles. Both studies also found a significant decrease in match day minus 1 (MD-1) for internal TL based on session rating of perceived exertion (s-RPE). In addition, study 1 observed a minor variation in external and internal TL during the in-season, which confirms the findings of study 2.

Despite the findings of studies 1 and 2 regarding s-RPE, a pattern cannot be found in the data collected from one-, two- or three-game weeks. This contrasts with the pattern noted by previous studies (Anderson et al., 2016; Jeong, Reilly, Morton, Bae & Drust, 2011; Owen et al., 2016) that higher values of s-RPE were found at the beginning of the different microcycles. In addition, Clemente et al. (2017) found significant differences in s-RPE between one- and two-game weeks. They also observed smaller values of s-RPE in two-game weeks compared to one-game weeks. The authors consequently suggested that s-RPE may be sensitive to congested periods, but not sensitive to regular periods of training during one-game weeks (Clemente et al., 2017). However, the results found in study 2 are not in accordance with Clemente et al. (2017). In addition, no differences were found between players' positions regarding s-RPE in study 1, which is not in line with previous studies (Bradley et al., 2009; Malone et al., 2015). The present findings corroborate the argument that rating of perceived exertion (RPE) may be a psychophysiological and volatile construct (Ferraz et al., 2017; 2018; Gibson, Lambert, Rauch & Tucker, 2006; Renfree, Martin, Micklewright & Gibson, 2014).

Nevertheless, the average s-RPE TL during the observed microcycles was 254.8 au (with an average range of 33-342 au) and the accumulated weekly s-RPE in study 2 revealed there was no significant differences between microcycles, with a mean range of 243-277 au. These values are in line with the range (38-936 au) found by Scott, Lockie, Knight, Clark and Janse de Jonge (2013) but are higher than the value of 187 au determined by Jeong et al. (2011), both for elite soccer players. Moreover, the mean for the total weekly TL (based on s-RPE) corresponds to a range of 970-1110 au, as a reference for training session prescriptions. Study 2 also provides relevant information to quantify s-RPE during microcycles and mesocycles and to establish guidelines for soccer training periodization.

In the study 1, hooper index (HI) was analysed and revealed no variation among all observed training days, except for the day immediately following the match. These data are in line with Haddad et al. (2013), who suggested that fatigue, stress, Delayed Onset Muscle Soreness (DOMS) and sleep are not major contributors to perceived exertion during traditional soccer trainings

without excessive TL. When comparing players' positions, no differences were determined regarding HI scores, which is in opposition to the findings of Clemente et al. (2017). In study 2, instead of HI, Creatine Kinase (CK) was analysed. However, this measure revealed high variability, especially for high CK values. Additionally, since CK was only collected 48h prior to the matches, it was not possible to determine the real potential to quantify internal TL.

As mentioned above, studies 1 and 2 found that external TL decreased until MD-1, possibly due to minimal fatigue as match day (MD) approached. Study 2 also observed that MD-1 was significantly lower than MD-2, independent of the number of games per week. Stevens, Ruiter, Twisk, Savelsbergh and Beek (2017) reported the highest external TL on the first training-day of the week, while Akenhead, Harley and Tweddle (2016) reported it on the second training-day of a 1-game week. In addition, Anderson et al. (2016) reported the highest external TL on the second training-day for 1- and 2-game weeks. Finally, many studies involving the English Premier League teams have also found that, during a typical week-pattern microcycle (i.e. 6 full days between matches), the day prior to the match (MD-1) has the lowest TL and the first days after the match has the high TL (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015). These findings can be used to identify similar patterns regarding increases in external TL in the first 2 days following the match and a decrease in external TL until MD-1, independent of the number of games per week.

Furthermore, study 1 it was observed that players covered a greater total distance at the beginning (M1 and M3) compared to the end mesocycle (M10) during the in-season. The higher distances covered at the beginning of the in-season may be due to the coaches continuing to emphasise physical conditioning immediately after the pre-season. In addition, the lower values in distance covered for M10 could be associated with the in-season ending and a consequent reduction in external TL.

Regarding weekly averages for external TL, all obtained data from studies 1 and 2 are within similar ranges to other studies: training duration, 65-77 min; total distance, 3898-5667 m and HSRD, 41-205 m, respectively (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015; Scott et al., 2013; Stevens et al., 2017). The following table presents the average interval ranges for one-game weeks.

Table 1. Average interval ranges values for external and internal TL variables with one-game week.

Variables	One-game week
Total Distance (m)	2735.3 - 8409.0
Average Speed (m/min)	41.4 - 243.8
HSD, >19km/h (m)	72.4 - 274.8
Duration (min)	20.4 - 88.0
s-RPE (au)	33.6 - 432.0
Fatigue (au)	2.8 - 4.4
Stress(au)	2.3- 3.9
Muscle Soreness (au)	2.8 - 4.4
Sleep Quality (au)	1.9 - 2.7
Total HI (au)	10.2 - 15.4

HSD = high-speed distance; s-RPE = session rating of perceived effort; HI = Hooper index; au = arbitrary units.

It appears that external TL is also maintained during the in-season. This maintenance could be associated with the need to establish a typical and stable weekly pattern including recovery activities after and between matches (Moreira et al., 2015), specially for elite soccer players. This seems to happen in the majority of Elite European soccer teams, as it enables them to be really prepared to win matches, prevent accumulated fatigue, non-contact injuries and illness and ensure an optimal level of physical fitness (Malone et al., 2018; Soligard et al., 2016). Therefore, seems not to be appropriate to reach a specific peak for strength and conditioning in soccer training during the season (Malone et al., 2015).

The results demonstrate limited variation between player positions regarding external TL. For instance, central midfielders (CMs) covered higher total distance (5502 m) than central defenders (CDs) (5052 m), wide defenders (WDs) (5388 m), wide midfielders (WMs) (4918 m) or strikers (STs) (4694 m), although the data was not statistically significant. The only differences between player positions occurred in M1, and these differences probably are associated with a particular concern of tasks related to the coach's game model in this phase of the season.

Some studies (Clemente et al., 2017; Malone et al., 2015; 2018; Morgans, Adams, Mullen, McLellan & Williams, 2014) have also reported limited relevant variation in TL throughout the in-season. This seems to suggest that the daily training practices of professional soccer teams follow a regular load pattern because there is a need to win games (Malone et al., 2015) and congestive periods prevent higher intensity variation of training sessions between matches to avoid accumulative fatigue.

Despite the results obtained, more research is needed on this topic, and it indeed seems pertinent to continue TL quantification for top elite soccer teams to confirm the obtained results.

Some limitations of this thesis can be addressed:

- (i) Studies 1-2 focused on analysing TL during training sessions, but the results are not representative of the effort exerted by players during a soccer game;
- (ii) The type of exercise training program applied to quantify TL was not taken into consideration;
- (iii) Only study 2 provided data from matches and CK. These records could be very important to improve the analysis of the results presented in study 1;
- (iv) In study 2, HI was not analysed;
- (v) The team analysed won around 78% of the matches and, therefore, the results presented need to be confirmed by analysing other teams with similar but also different winning percentages;
- (vi) Study 1 only included regular, one-game weeks. Therefore, future research should include regular and congestive periods to improve the validity of the results.

Chapter 5. Overall Conclusions

This thesis highlights the training load (TL) quantification of a top elite soccer team by comparing 10 in-season mesocycles and one-, two-, and three-game microcycles.

All conducted studies provide new information with potential practical applications for soccer coaches. They allow to obtain references about the periodization pattern observed across a full competitive season and allow generate reference values for elite players that can be considered for the coaches in the control and monitoring of the training load.

The main conclusions of the present thesis are:

- I. Despite the existence of some significant differences between mesocycles, changes in internal and external TL variables across the in-season period are minor.
- II. Match-day minus 1 presented a reduction in external TL (regardless of mesocycle), while internal TL variables did not have the same result for match-day minus 1, at least in all microcycles analysed in study 2.
- III. A similar pattern is exhibited for one- and two-game week microcycles for the day before the match, which exhibits a decrease in all external variables and (rating of perceived exertion (RPE)).
- IV. Distances covered at different thresholds presented higher values in match day minus (MD-5) and successfully decrease until MD-1, which is in line with session rating of perceived exertion (s-RPE);
- V. Despite the different number of games played per week, the TL remained similar between microcycles for zones 2 and 5, plus s-RPE;
- VI. S-RPE remained similar during in-season, except for a decrease in MD-1, however there were found some microcycles with different results in study 2;
- VII. Hooper index scores remained similar during the in-season, except for the day after a match, which exhibited higher increments for the team analysed;
- VIII. Creatine Kinase did not appear to be relevant for TL quantification;
- IX. External TL, when measured by distances covered at different threshold speeds using a Global Positioning System indicates that the real applied load can be different from internal TL.

Chapter 6. Suggestions for future investigations

This study has reached several conclusions about a top elite European soccer team regarding training load (TL) quantification. Furthermore, it provides useful information relating to the TL employed by top elite European Soccer players that played in a European Competition and provides evidence that a combination of different TL measures should be used to comprehensively evaluate the periodization pattern observed across a full competitive season. For coaches and practitioners, this thesis generates reference values for elite players that can be considered in the control and monitoring the training load during the season.

Future research into soccer TL quantification should consider the following suggestions:

- I. To consider a larger sample, by including the reserve squad and the main team or, if possible, consider more teams;
- II. To analyse and compare different levels (Elite or not) of teams and teams from different leagues and countries;
- III. To compare congested weeks with non-congested weeks;
- IV. To use the sum of weekly session rating of perceived exertion (s-RPE), monotony index, strain index and the s-RPE acute/chronic workload ratio to better understand player's effort;
- V. To continue to use the hooper index to expand and validate knowledge of this variable;
- VI. To investigate TL quantification regarding contextual variables such as match result, match location, quality of the opponents' teams and tactical systems;
- VII. To collect creatine kinase 48h prior and 48h following the match-day.

Chapter 7. References

Chapter 1, General Introduction

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Chapter 4. General Discussion

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Appendix I

In-season internal and external training load quantification of an elite European soccer team

Abstract

Introduction: Elite soccer teams that participate in European competitions often have a difficult schedule, involving weeks in which they play up to three matches, which leads to acute and transient subjective, biochemical, metabolic and physical disturbances in players over the subsequent hours and days. Inadequate time recovery between matches can expose players to the risk of training and competing whilst not fully recovered. Controlling the level of effort and fatigue of players to reach higher performances during the matches is therefore critical. Therefore, the aim of the current study was to provide the first report of seasonal internal and external training load (TL) that included Hooper Index (HI) scores in elite soccer players during an in-season period. **Methods:** Sixteen elite soccer players were sampled, using global position system, session rating of perceived exertion (s-RPE) and HI scores during the daily training sessions throughout the 2015-2016 in-season period. Data were analysed across ten mesocycles (M: 1 to 10) and collected according to the number of days prior to a match. **Results:** Total daily distance covered was higher at the start (M1 and M3) compared to the final mesocycle (M10) of the season. M1 (5589m) reached a greater distance than M5 (4473m) (ES = 9.33 [12.70, 5.95]) and M10 (4545m) (ES = 9.84 [13.39, 6.29]). M3 (5691m) reached a greater distance than M5 (ES = 9.07 [12.36, 5.78]), M7 (ES = 6.13 [8.48, 3.79]) and M10 (ES = 9.37 [12.76, 5.98]). High-speed running distance was greater in M1 (227m), than M5 (92m) (ES = 27.95 [37.68, 18.22]) and M10 (138m) (ES = 8.46 [11.55, 5.37]). Interestingly, the s-RPE response was higher in M1 (331au) in comparison to the last mesocycle (M10, 239au). HI showed minor variations across mesocycles and in days prior to the match. Every day prior to a match, all internal and external TL variables expressed significant lower values to other days prior to a match ($p < 0.01$). In general, there were no differences between player positions. **Conclusions:** Our results reveal that despite the existence of some significant differences between mesocycles, there were minor changes across the in-season period for the internal and external TL variables used. Furthermore, it was observed that periodization of external TL was typically reduced until MD-1 (regardless of mesocycle) while internal TL variables did not have the same record.

Keywords: Soccer Training; Internal Load; External Load; Training Load; Periodization.

Appendix II

In-season training load quantification of one-, two- and three-game week schedules in a top European professional soccer team

Abstract

Introduction: Top European soccer teams that play in UEFA competitions often participate in one, two- or three-games per week. Therefore, it is necessary to ensure optimal match-day performance and full recovery. The aim of this study was to quantify internal and external TLs within five microcycles: M1 and M2 - one-game weeks; M3 and M4 - two-game weeks; M5 - three-game week). **Methods:** Thirteen elite soccer players participated in this study. A global positioning system (GPS) was used to measure the total distance covered and distances of different exercise training zones (1-5), the session ratings of perceived exertion (s-RPE) scores and the amount of creatine kinase (CK) created during daily training sessions for the 2015-2016 in-season period. The data were analysed with respect to the number of days prior to a given match. **Results:** The main results indicate a significant difference in training intensity for zone 1 between M2 and M4 (4010.2 ± 103.5 and 4507.6 ± 133.0 m, respectively); a significant difference in training intensity for zone 3 between M1 and M5 (686.1 ± 42.8 and 801.2 ± 61.2 m, respectively); a significant difference in the duration of the training sessions and matches between M2 and M5 (69.2 ± 2.1 and 79.6 ± 2.3) and M3 and M5 (69.7 ± 1.0 and 79.6 ± 2.3); and finally, there was a significant difference in CK between M3 and M2 (325.5 ± 155.0 and 194.4 ± 48.9). Moreover, there was a significant decrease in TL in the last day prior to a match, for all microcycles and all variables. There was no significant difference with respect to s-RPE. **Conclusions:** This study provides the first report of daily external and internal TLs and weekly accumulated load (training sessions and match demands) during one, two, and three-game week schedules in a group of elite soccer players. Expected significant differences are found in daily and accumulated loads for within- and between-game schedules. A similar pattern is exhibited for one- and two-game week microcycles regarding the day before the match, which exhibits a decrease in all variables. Despite the different number of games played per week, TL remain similar between microcycles for zone 2 and 5, plus s-RPE.

Keywords: Soccer Training; Internal Load; External Load; Training Load; Periodization; GPS